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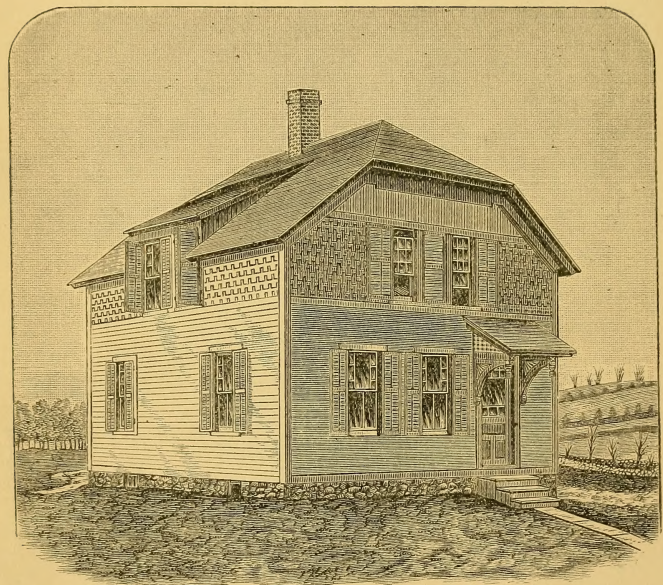

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State of Connecticut.

FIRST ANNUAL REPORT

OF THE

STORRS SCHOOL
AGRICULTURAL EXPERIMENT STATION,

STORRS, CONN.,

1888.

Printed by Order of the General Assembly.

HARTFORD, CONN.:
PRESS OF THE CASE, LOCKWOOD & BRAINARD COMPANY.
1889.

THE CONNECTICUT AGRICULTURAL COLLEGE
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BOARD OF TRUSTEES

OF THE

STORRS AGRICULTURAL SCHOOL.

His Excellency, MORGAN G. BULKELEY,
E. H. HYDE,
J. P. BARSTOW,
W. E. SIMONDS,
S. W. JOHNSON,
T. S. GOLD,
J. M. HUBBARD,
H. C. MILES,
J. H. HALE.

OFFICERS OF THE STATION.

EXECUTIVE COMMITTEE.

T. S. GOLD, West Cornwall, } *Of the Board of Trustees of*
J. M. HUBBARD, Middletown, } *Storrs Agricultural School.*
B. F. KOONS, Storrs, *Principal of the School.*

TREASURER.

JOHN P. BARSTOW, Norwich.

WORKING FORCE.

*W. O. ATWATER, *Director.*
C. S. PHELPS, *Vice-Director.*
C. D. WOODS, *Chemist.*
H. B. GIBSON, *Assistant Chemist.*
E. A. BAILEY, *Assistant in Farm Experiments.*

---

*Since October 1st, the Director has been engaged in the direction of the Office of Experiment Stations of the U. S. Department of Agriculture, and has been able to exercise only a general supervision of the work of the Station.

REPORT OF THE EXECUTIVE COMMITTEE.

To his Excellency MORGAN G. BULKELEY, *Governor of Connecticut:*

In accordance with a resolution of the General Assembly, approved May 18, 1887, concerning congressional appropriations to agricultural experiment stations, and an act of the General Assembly, approved March 6, 1889, entitled "An Act relating to the publication of Reports of the Storrs School Agricultural Experiment Station," we have the honor to present the first Annual Report of the Storrs School Agricultural Experiment Station.

RESOLUTION OF THE GENERAL ASSEMBLY, APPROVED MAY 18, 1887.

Concerning Appropriations to Agricultural Experiment Stations.

Resolved by this Assembly:

SECTION 1. That this State accepts and assents to the provisions of the Act of Congress, approved March second, 1887, entitled "An Act to establish Agricultural Experiment Stations in connection with the colleges established in the several States, under the provisions of an act approved July second, 1862, and of the acts supplementary thereto."

SEC. 2. The farm attached to the Storrs Agricultural School may be used as an experimental farm for the purposes specified in the act first mentioned; and the trustees of that school and their successors in office are hereby appointed to receive and expend one-half of such moneys as may come to this State, under the provisions of said act first mentioned.

SEC. 3. The board of control of the Connecticut Agricultural Experiment Station, and its successors in office, is hereby appointed to receive and expend one-half of such moneys as may come to this State, under the provisions of said act first mentioned.

Approved, May 18, 1887.

AN ACT RELATING TO THE PUBLICATION OF REPORTS OF THE STORRS SCHOOL AGRICULTURAL EXPERIMENT STATION.

Be it enacted by the Senate and House of Representatives in General Assembly convened:

SECTION 1. The Annual Report of the Storrs School Agricultural Experiment Station shall be printed, bound, and circulated as now provided by law for the Annual Report of the Connecticut Agricultural Experiment Station at New Haven.

SEC. 2. This act shall take effect from its passage.

At the annual meeting of the trustees of the Storrs Agricultural School, held in Hartford, February 1, 1888, it was

Resolved, That a committee of three be appointed to prepare plans for experimental work at the Storrs School under the Hatch Bill, and to confer with the Board of Control of the Connecticut Experiment Station as to harmony of work.

T. S. Gold, J. M. Hubbard, and H. C. Miles, were appointed the committee.

At a meeting of trustees, held at Hartford, March 27th, Mr. Hubbard reported for committee our plans for experimental work. After amendment, the report was accepted and adopted, appointing Prof. Atwater director, and Prof. C. S. Phelps vice-director. The amended report was essentially as follows:

REPORT OF COMMITTEE.

The committee recommend that the Experiment Station of the Storrs Agricultural School be organized by the appointment of a Director, Vice Director, and an Executive Committee of three members, two of whom shall be selected by the board of Trustees from its own number, and one shall be the principal of the School.

The Director, Vice-Director, and two members of the Executive Committee, shall be chosen yearly at the annual meeting of the Trustees, and shall hold their positions until their successors are elected, or until such positions are vacated by action of the trustees.

The Executive Committee shall, upon consultation with the Director, determine the general line of employment of assistants, and the expenditure of money by the Director must be with their advice and approval.

The Director shall have the general superintendence of all work undertaken by this Station. He shall arrange the details of all the experiments, and with the advice and approval of the Executive Committee shall employ such assistants as may be necessary to carry on the work, and arrange for their compensation.

The Vice-Director shall reside at the School, and shall have particular charge of all the work of the department localized there, including general correspondence and accounts, and such supervision of work elsewhere as may be devolved upon him by the Director and Executive Committee. He may also render such assistance as an instructor at the School as may be arranged for without neglect of other duties.

The committee recommend that the office of director be filled by the appointment of Prof. W. O. Atwater of Middletown, and that the office of vice-director be filled by the appointment of Mr. C. S. Phelps of West Hartford.

The committee recommend that so much of the first year's appropriations as may be used in the erection of buildings be expended upon a building for conducting feeding experiments with domestic animals, and another for office and library uses. It shall be a recognized function of this department to communicate freely with the farmers of the State, both in regard to results attained and work to be undertaken. It will labor for the establishment and maintenance of very intimate and mutually helpful relations between itself and them.

It proposes to be guided by their intelligent desires in the line of work to be undertaken, and hopes for their active co-operation in carrying it forward.

To this end it invites the assistance of all agricultural societies, granges, farmers' clubs, and all associations which may help it or be helped by it, in the work of promoting the welfare of Connecticut agriculture.

The Executive Committee met at New Haven, April 7th, and the general plan of work outlined by the Director was approved, and authority given for its prosecution.

At subsequent meetings, authority for the examination and approval of bills was delegated to Mr. Hubbard of the committee, and the Director, the matter of the regular quarterly bulletins was considered, and from time to time, the employment of such assistants as appeared to be necessary was authorized.

The Trustees subsequently so modified their instructions to the committtee as to permit the expenditure of the entire sum available for buildings, from the first year's appropriation, upon one building for library and office uses, as it was found that a satisfactory structure could not be erected for less than that sum. The building erected is 24 x 26 feet, one and one-half stories in height, and in addition to the $1,500 expended upon the building itself, fixtures for lighting, heating, and water supply have cost the sum of $268.90, and furniture and interior fittings the sum of $285.

The Executive Committee have endeavored to keep always in view the declarations recommended by the committee on organization, and adopted by the Trustees, to aid them in the line and scope of work to be undertaken. In this they have had the hearty co-operation of the officers and employees of the Station, to whose zeal and industry they are happy to bear testimony. It will be understood that much of the first year's work was necessarily of a preparatory nature, but it is the confident belief of the Committee that a good beginning has been made in an enterprise destined to prove of great value to the agriculture of Connecticut.

The Committee refer to the accompanying report of the Treasurer for details of expenditure and to that of the Director and his assistants for the history of the work accomplished.

Respectfully submitted,

T. S. GOLD,
J. M. HUBBARD, } *Executive Committee.*
B. F. KOONS,

ORGANIZATION AND OPERATIONS OF THE STATION.*

By the act of Congress provision is made for the appropriation of $15,000 per annum to each State and Territory, for the maintenance of Agricultural Experiment Stations. Of the fund for Connecticut, one-half is, by act of its last Legislature, entrusted to the board of control of the State Experiment Station, and one-half to the board of trustees of the Storrs Agricultural School. At the time of the establishment of the Station, the trustees were: His Excellency, Phineas C. Lounsbury, E. H. Hyde, T. S. Gold, J. M. Hubbard, J. P. Barstow, Wm. E. Simonds, Henry C. Miles, S. W. Johnson.

Two members of the board, Messrs. T. S. Gold and J. M. Hubbard, with Prof. B. F. Koons, principal of the school, constitute the Executive Committee of the Station. The appropriation was actually secured for the Storrs School in March, 1888. As soon as practicable thereafter a director, Prof. W. O. Atwater, and a vice-director, C. S. Phelps, were appointed, and entered upon their duties April 1st. Arrangements were then made to commence work at once.

The farm and farm appliances, and the labor of the students of the Storrs School, are utilized by the Station. A building has been erected for the office of the Station on the grounds of the School. The work at Mansfield, the Grass and Forage Garden there and the field experiments throughout the State, are under the immediate charge of the Vice-Director. The more purely scientific investigations are carried out at Middletown, in the chemical laboratory of Wesleyan University.

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* This account of the organization and work of the Station was presented with the report of the Treasurer which follows, to the Governor of the State, in January, for record and transmittal to the Commissioner of Agriculture, and the Secretary of the Treasury of the United States, in accordance with the Act of Congress approved March 2, 1887.

The work actually undertaken up to June 30, 1888, included:

Co-operative field experiments on the effects of fertilizers and the production of crops. These have been performed by the Station in Mansfield, and by a considerable number of farmers under the direction of the Station, in all of the counties of the State.

Vegetation experiments in pots and boxes for studying the sources of nitrogen of plants.

The establishment of a Grass and Forage Garden to test the adaptability of grasses and other plants for culture in Connecticut.

Plans were made for experiments upon the effects of surface tillage upon soil moisture, for the study of the root development of plants, and of the values of foods and feeding stuffs, by chemical analysis, and experiments with the calorimeter.

From June 30 to December 31, 1888, the force of the Station has been chiefly engaged in carrying out the lines of experimenting indicated above.

The field experiments have demanded a good deal of personal attention of the Vice-Director, and involved no little travel through the State.

The experiments upon the sources of nitrogen of plants have occupied a considerable portion of the labor and thought of the Chemist and Assistant Chemist. The effects of soil infusions and of bacteria obtained from cultures have been studied. More than one hundred pots of plants (peas, corn, cow peas, and others) have been grown with varying success.

Meteorological observations, as explained in Bulletin No. 2, are regularly made three times each day at the Station.

During the growing season the rainfall was noted by observers at thirteen different localities in the State.

The work in the chemical laboratory has included analysis of the plants and soils from the pot experiments, of the roots mentioned above, and of thirty-six specimens of food and fodder materials, studies of some methods of analysis, and the beginning of a series of analyses of samples of corn and stover from certain of the field experiments.

Under the direction of Dr. H. W. Conn, Professor of biology in Wesleyan University, an investigation of the micro-organisms that have to do with fermentation and other changes that take place in milk and during the ripening of cream, has been undertaken.

The organization and first work of the Station, including field experiments, were described in Bulletin No. 1. The work of the Vice-Director and his assistant in the Grass and Forage Garden, and their experiments on the effects of surface tillage, were described in the Bulletin No. 2. Their observations on the roots of plants, and the results of analyses of roots by the Chemist were given in Bulletin No. 3.

During the whole period here reported upon, and especially that previous to June 30th, the Executive Committee have given their personal attention to the affairs of the Station, visiting Mansfield frequently and spending much time in so doing.

REPORT OF THE TREASURER FOR FISCAL YEAR ENDING JUNE 30, 1888.

Here follow:

(1) A list of the bills approved by the Executive Committee and Director, and paid by the Treasurer, with statement of what each bill was for.

(2) The statement of the Treasurer which, with the vouchers of above list, was examined by the State Auditors and certified by them.

(3) Summary of receipts and expenditures.

Copies of the statement (2) and summary (3) were duly presented to the Governor of the State in January for record and transmission to the Commissioner of Agriculture and the Treasurer of the United States.

BILLS APPROVED BY EXECUTIVE COMMITTEE AND PAID BY TREASURER.

1.	E. N. Darling, horse, . . .	$200.00
2.	E. N. Darling, harness, . . .	15.00
3.	E. A. Stearns & Son, horse-blanket, robes, etc., ...	15.25
4.	Estate S. N. Hart, buggy, . . .	80.00
5.	J. P. Barstow & Co., miscellaneous farm tools, ...	44.76
6.	William H. Brown, type-writing machine, .	83.00
7.	E. P. Taylor, seed, ...	3.75
8.	Eimer & Amend, bacteriological apparatus,	48.23
9.	Eimer & Amend, chemicals, . .	2.15
10.	Educational Supply Co., microscope and accessories, ...	105.00
11.	Scribner & Welford, books for library, .	26.52
12.	C. S. Phelps, traveling expenses, . .	100.00
13.	C. S. Phelps, farmers for field experiments,	100.00
14.	E. W. Rockwood, salary, . . .	100.00
15.	Boston Furniture Co., roll-top desk, .	45.00
16.	W. H. Brown, type-writer desk and copy-holder, ...	32.00
17.	The Mapes Formula and Peruvian Guano Co., fertilizers, ...	367.20
18.	E. W. Rockwood, traveling expenses, .	19.68
19.	Whitall, Tatum & Co., apparatus for pot experiments, ...	82.95
20.	Peter Henderson & Co., seeds, . .	.43
21.	Emil Greiner, chemical apparatus, . .	29.30
22.	Henry Woodward, chemicals, . .	1.30
23.	Athol Machine Co., chopper, . .	4.50
24.	Henry J. Green, thermometers and rain gauges, ...	23.85
25.	A. C. Raymond, blank book, . .	4.50
26.	F. W. Christern, books for library, .	24.00
27.	G. R. Burdick, paper boxes, . .	1.92

28.	W. H. Brown, carbon paper,	$1.00
29.	L. R. Hazen, Manilla envelopes, etc.,	55.30
30.	W. O. Atwater, cash advanced to stenographer and type-writer,	60.00
31.	W. O. Atwater, traveling expenses, etc.,	32.29
32.	E. W. Rockwood, cash advanced for express, postage, and telegrams,	14.31
33.	E. W. Rockwood, salary,	100.00
34.	C. S. Phelps, salary,	200.00
35.	E. A. Bailey, salary,	52.50
36.	Storrs Agricultural School, board of Mr. Bailey,	40.86
37.	Carpenter & Fowler, hardware,	6.72
38.	E. F. Sheldon, desk,	76.50
39.	O. N. Oswell, rain gauges,	94.00
40.	Philo W. Thompson, labor,	8 00
41.	Storrs Agricultural School, labor,	18.55
42.	Storrs Agricultural School, student labor,	41.18
43.	Levi S. Deming, coal,	3.13
44.	J. W. Hubbard & Co., sand,	4.60
45.	S. T. Camp, sand and oil,	9.95
46.	Eimer & Amend, chemicals,	5.51
47.	Educational Supply Co., chemical apparatus,	25.75
48.	Eimer & Amend, chemicals,	28.20
49.	James Donovan, oil stoves,	11.50
50.	Lyman D. Mills, copper, iron, and labor,	32.48
51.	Scribner & Welford, books for library,	1.89
52.	Gustav E. Stechert, books for library,	42.50
53.	Scribner & Welford, books for library,	9.26
54.	T. H. Clark, traveling expenses,	1.60
55.	Storrs Agricultural School, board of horse,	15.75
56.	C. S. Phelps, traveling expenses ($81.90) and sundries,	100.00
57.	H. E. Miles, expenses and services,	15.25
58.	T. S. Gold, expenses ($95.97) and services,	195.97
59.	J. M. Hubbard, expenses and services,	100.00
60.	N. A. Stearns & Sons, robes and harness,	26.50
61.	N. A. Stearns & Sons, halters,	3.00
62.	W. H. Latham & Co., sponge,	.40

63.	J. A. Kellogg, bed-room furniture, .	$119.00
64.	Keigwin & Clark, toilet sets, . .	10.00
65.	W. H. Post & Co., carpet, . . .	22.00
66.	W. H. Latham & Co., library shelves, etc.,	67.15
67.	E. Paddock, chairs, etc., . . .	49.00
68.	L. R. Hazen, copying apparatus, . .	6.50
69.	L. R. Hazen, letter scales, etc , . .	4.30
70.	Charles R. Utley, record-book and paper, .	5.38
71.	L. R. Hazen, rubber stamps, etc., . .	8.00
72.	Eimer & Amend, chemical apparatus, .	239.86
73.	Henry J. Green, meteorological apparatus,	115.05
74.	B. F. Koons, traveling expenses, . .	14.80
75.	J. P. Barstow, traveling expenses ($8.23) and services, ...	33.23
76.	Pelton & King, printing, . . .	47.00
77.	W. O. Atwater, salary, . . .	375.00
78.	E. W. Rockwood, salary, . . .	100.00
79.	W. H. Latham & Co., lumber and labor, .	17.82
80.	D. H. Snow, labor, . . .	16.29
81.	L. R. Hazen, boxes, . . .	1.20
82.	W. H. Latham & Co., tools, etc., . .	65.00
83.	J. P. Barstow & Co., tools, etc., . .	17.20
84.	W. H. Latham & Co., lumber and labor, .	42.85
85.	E. M. Rockwood, cash advanced for expenses, etc., ...	7.75
86.	George F. King, telephone poles, . .	15.00
87.	Milo Millard, telephone poles, . .	91.25
88.	Storrs Agricultural School, clerical work, .	10.50
89.	L. R. Hazen, envelopes for bulletins, .	104.80
90.	W. H. Latham & Co., library and office building, ...	1,500.00
91.	L. R. Hazen, books for library, . .	56.68
92.	Robinson & Abell, lumber and labor, .	27.80
93.	Charles Gilbert, lumber and labor, . .	50.88
94.	T. H. Clark, labor, ...	25.00
95.	H. W. Conn, labor, . . .	50.00
96.	L. S. Deming, coal, . . .	3.61
97.	L. R. Hazen, mailing June bulletin, .	61.93
98.	The Case, Lockwood & Brainard Co., printing June Bulletin, . . .	9.00

99.	The Case, Lockwood & Brainard Co., printing June Bulletin,		$200.55
100.	J. P. Barstow, traveling expenses,		3.15
101.	T. H. Clark, salary,		50.00
102.	W. O. Atwater, cash advanced stenographer and type-writer,	$32.00	
	Cash advanced for manual labor in laboratory,	22.50 —	54.50
103.	C. S. Phelps, paid farmers for field experiments,		150.00
104.	W. O. Atwater, traveling expenses,		6.25
105.	W. O. Atwater, for B. F. Stevens, books for library,		16.00
106.	L. R. Hazen, books for library,		113.67
107.	L. R. Hazen, books for library,		98.50
108.	Wesleyan University, chemical apparatus,		164.75
109.	Wesleyan University, apparatus for pot experiments,		28.50
110.	Wesleyan University, chemical apparatus and chemicals,		229.99
			$7,501.43

STATEMENT OF THE TREASURER.

John P. Barstow, Treasurer, Storrs School Agricultural Experiment Station.

Dr.

1888.			
March 9.	U. S. Treasury,	$3,750.00	
April 1.	U. S. Treasury,	1,875.00	
June 29.	U. S. Treasury,	1,875.00	
	Interest,	1.43	
			$7,501.43

Cr.

1888.		
March 29.	L. D. Merrill,	3.15
April 16.	C. S. Phelps,	100.00
May 1.	E. N. Darling,	200.00
11.	C. S. Phelps,	15.00
	C. S. Phelps,	100.00

May 11.	N. A. Stevens,	$15.25
	Estate T. W. Hart,	80.00
	J. P. Barstow,	44.76
	W. G. Brown,	83.00
	Fred P. Taylor,	3.75
	Eimer & Amend,	50.38
	Educational Supply Co.,	105.00
	Scribner & Welford,	26.52
21.	E. W. Rockwood,	100.00
June 16.	E. W. Rockwood,	133.99
	W. O. Atwater,	92.29
19.	Mapes, F. & P. Guano Co.,	367.20
21.	L. R. Hazen,	55.30
	Whitall & Tatum,	82.95
	Peter Henderson & Co.,	.43
	Emil Greiner,	29.30
	Henry Woodward,	1.30
	Athol Machine Co.,	4.50
	H. J. Green,	23.85
	A. C. Raymond,	4.50
	F. W. Christien,	24.00
	G. R. Burdick,	1.92
	Boston Furniture Co.,	45.00
	W. H. Brown,	33.00
25.	C. S. Phelps,	300.00
	E. A. Bailey,	52.50
	H. E. Miles,	15.25
	J. M. Hubbard,	100.00
	T. S. Gold,	195.97
26.	Storrs Agricultural School,	116.34
27.	P. W. Thompson,	8.00
	T. H. Clark,	1.60
	Scribner & Welford,	9.26
	G. E. Stechert & Co.,	42.50
	Scribner & Welford,	1.89
	L. D. Mills,	32.48
	James Donovan,	11.50
	Carpenter & French,	6.72
	E. F. Sheldon,	76.50

June 27.	O. N. Oswell,	$94.00	
	L. S. Deming,	3.13	
	J. M. Hubbard & Co.,	4.60	
	Educational Supply Co.,	25.75	
	S. T. Camp,	9.95	
	Eimer & Amend,	33.71	
30.	E. Paddock estate,	49.00	
	W. O. Atwater,	375.00	
	E. W. Rockwood,	107.75	
	M. Millard,	91.25	
	J. P. Barstow & Co.,	17.20	
	Storrs Agricultural School,	10.50	
	W. H. Latham,	193.22	
	David H. Snow,	16.29	
	George F. King,	15.00	
	H. J. Greene,	115.05	
	Charles R. Utley,	5.38	
	Pelton & King,	47.00	
	B. F. Koons,	14.80	
	L. R. Hazen,	181.48	
	W. H. Post & Co.,	22.00	
	N. A. Stearns & Son,	29.50	
	J. A. Kellogg,	119.00	
	Kweigin & Clark,	10.00	
	J. P. Barstow,	33.23	
	T. H. Clark,	75.00	
	H. W. Conn,	50.00	
	C. S. Phelps,	150.00	
	L. R. Hazen,	274.10	
	Robinson & Abell,	27.80	
	Charles Gilbert,	50.88	
	L. S. Deming,	3.61	
	The Case, Lockwood & Brainard Co.,	209.55	
	Wesleyan University,	423.24	
	W. O. Atwater,	76.75	
	Eimer & Amend,	239.86	
	W. H. Latham & Co.,	1,500.00	
			$7,501.43

This is to certify that we, the undersigned, Auditors of the Public Accounts, appointed by the State of Connecticut, have examined the accounts of J. P. Barstow, Treasurer of the Storrs Agricultural School, and find that the sum of seven thousand five hundred and one dollars and forty-three cents has been expended for the Experiment Station.

(Signed,) FRANK P. RODGERS, } *Auditors of*
JOHN E. SCANLAN, } *Public Accounts.*

HARTFORD, October 19, 1888.

TABULAR STATEMENT OF THE FOREGOING EXPENDITURES.

Storrs School Agricultural Experiment Station of Connecticut,
In account with the United States Treasury Department.

1888.	Dr.		
March.	U. S. Treas. check,	$3,750.00	
April.	U. S. Treas. check,	1,875.00	
June.	U. S. Treas. check,	1,875.00	
June.	Interest,	1.43	
			$7,501.43
1888.	Cr.		
Buildings,		$1,500.00	
Salaries of officers,		1,018.36	
Agricultural implements,		133.68	
Team and outfit,		340.15	
Office and laboratory furniture,		514.45	
Field experiments,		843.92	
Pot and box experiments,		258.35	
Apparatus,		1,095.92	
Books,		393.52	
Stationery,		71.60	
Printing and publishing,		433.78	
Telephone,		106.25	
Executive Committee, including traveling expenses,		362.40	
Traveling expenses of Vice-Director,		181.90	
Incidentals,		247.15	
			$7,501.43

J. P. BARSTOW, *Treasurer.*

REPORT OF THE DIRECTOR.

The following is a report of as much of the work of the Station as can be conveniently described at this date, January 1, 1889. It includes accounts of —

1. Experiments on the effects of tillage upon soil moisture. Experiments of this sort go far towards explaining why hoeing and cultivating help crops to withstand drouth.
2. Investigations on the value of roots of plants as manure. These show the large manurial value of roots and stubble, and with other like investigations help to explain what crops leave the most fertilizing material for the use of succeeding crops, and one of the advantages of rotation.
3. Accounts of meteorological observations made at the station and by farmers in various parts of the State in connection with field experiments.
4. Report of co-operative field experiments with fertilizers by the station, and by farmers on their own farms in different parts of the State, for the purpose of testing the needs of soils and plants, and the most economical ways of supplying them. As an important part of this work is the chemical analysis of the products, which are to be made during the winter, the full results cannot be reported here, but must be reserved for later publication.
5. Grasses and forage plants grown by the Station in its Grass and Forage Garden and elsewhere. With this is a paper on the cow pea, for which the Station and the public are indebted to Prof. W. H. Brewer of Yale University.

Since October 1st, the Director has spent a large portion of the time in Washington in charge of the Office of Experiment Stations of the U. S. Department of Agriculture, and has been able to exercise only a general supervision of the work of the station. He wishes, however, to express his appreciation of the care and thoroughness with which details have been carried out and reported by the gentlemen to whom they have been entrusted.

W. O. Atwater, *Director.*

EXPERIMENTS ON THE EFFECTS OF TILLAGE ON SOIL MOISTURE.

The Station has undertaken, on the farm of the School at Mansfield, a series of experiments on the evaporation of soil moisture, especially as affected by surface tillage. They were planned by Prof. C. S. Phelps, Vice-Director of the Station, and carried out under his immediate supervision. The experiments thus far made have revealed no new principles — indeed, they are still crude and only tentative, and will need various modifications in the future — but they confirm the results of other experiments in explaining the value of surface tillage.

DESCRIPTION OF THE EXPERIMENTS.

The details of the experiments are as follows:

Eight cans made of galvanized iron, each thirty inches deep and ten inches in diameter, were used for holding the soil. A half-inch pipe connecting with the interior was soldered on the outside of the can two inches above the bottom. By means of a rubber tube extending from the pipe to the top of the can weighed quantities of water were added when desired. In the soil as it naturally lies, the water has free passage downwards and upwards, but the bottoms of the cans cut off communication between the soil in them and that in the earth in which they stand. Since, therefore, no water could come into them from below to make up for that which was evaporated, this means was taken to supply water in time of drouth. Boxes of one and one-half inch chestnut plank, without bottoms, of the same height as the cans and large enough to hold them, were sunk into the earth in the forage garden, so that the tops were even with the surface of the ground. The cans of soil were kept in these boxes and removed only for weighing. The surface of the soil within the cans was at the same level as that of the ground outside. On the top of each can a thin cylinder of galvanized iron two inches high and ten inches in diameter was accurately fitted. These cylinders served as rain gauges, conducting the same amount of rainfall into each can. The rainfall for August being above the average, water was added artificially but twice, all the cans receiving the same amounts.

Two kinds of soil were used for the experiments; one was from rather low land, that of the grass and forage garden, and the other from grass-land on the top of the hill near the laboratory of the school. The cans were filled so that the soil stood, as nearly as possible, at the same depth in the cans as it previously did in the fields from which it was taken. That is, soil from a depth of twenty to thirty inches was placed in the bottom ten inches of the can; soil from a depth of ten to twenty inches in the middle ten inches; and the upper part of the can was filled with the surface soil. The earth was put into the cans in successive layers of about one inch in depth, and each layer gently tamped in order to make the soil in the cans as uniform in compactness as possible.

The eight cans were divided into lots of four each. The soil in one lot was heavy loam with clayey subsoil; that in the other, light loam with sandy subsoil. The surface of the soil in two cans of each lot was stirred frequently — numbers 4 and 5 to a depth of two, and numbers 3 and 6 four inches, while the other cans were not disturbed.

Lot I.— (Nos. 1, 2, 3, and 4.) Soil from Forage Garden. Subsoil, lower twenty inches, a yellow clay loam of nearly uniform texture. Surface soil, top of can, a rich, heavy loam.

Lot II. — (Nos. 5, 6, 7, and 8.) Upland soil. Ten inches at the bottom of can nearly pure sand. Middle ten inches, porous, light loam. Remainder, top of can, from first five inches below the sod, a light loam, apparently containing small percentage of organic matter.

The experiment was commenced July 31st, but heavy rains interferred at times. In one case more water fell than the soil in the cans could readily absorb, so that the cans were flooded. The period between August 15th and August 31st, however, was for the most part dry and warm enough to show clearly the effects of evaporation, though it was by no means a time of drouth.

The following tables give the details of the experiment. The scales used for the weighing, which were the best that could be obtained at the time, were not delicate enough to make the weights as accurate as is desirable. Nevertheless, the average results, which agree with those of similar experiments elsewhere, are doubtless very nearly correct:

TABLE I.

Details of Experiment from August 15th to August 18th.

		No.	Aug. 15th. Weight.		Water added. *	Aug. 18th. Weight.		Loss in Weight.		Loss in Inches.
			lbs.	oz.	oz.	lbs.	oz.	lbs.	oz.	
Heavy loam,	Not stirred,	1	132	12.0	11	131	14.0	1	9.0	.55
		2	131	10.0	11	130	15.5	1	5.5	.48
	Stirred,	3	137	2.5	11	136	11.5	1	2 0	.40
		4	131	14.0	11	131	10.0	0	15.0	.33
Light loam,	Stirred,	5	139	5.5	11	139	9.0	0	7.5	.17
		6	141	5.0	11	141	5.0	0	11.0	.24
	Not stirred,	7	135	13.0	11	135	6.0	1	2.0	.40
		8	140	0.5	11	139	13.0	0	14.5	.32

* Including rainfall.

TABLE II.

Details of Experiment from August 22d to August 25th.

		No.	Aug. 22d. Weight.		Water added.	Aug. 25th. Weight.		Loss in Weight.		Loss in Inches.
			lbs.	oz.	oz.	lbs.	oz.	lbs.	oz.	
Heavy loam,	Not stirred,	1	139	2.0	0	138	4.0	1	5.0	.46
		2	138	14.5	0	137	13.0	1	1.5	.39
	Stirred,	3	145	8.5	0	144	7.0	1	1.5	.39
		4	141	2.0	0	139	13.0	1	5.0	.46
Light loam,	Stirred,	5	148	13.5	0	148	6.5	0	7.0	.15
		6	150	6.0	0	149	11.5	0	10.5	.23
	Not stirred,	7	144	6.5	0	143	1.5	1	5.0	.45
		8	148	10.0	0	148	3.0	0	7.0	.15

TABLE III.

Details of Experiment from August 25th to August 28th.

		No.	Aug. 25th. Weight.	Water added. *	Aug. 28th. Weight.	Loss in Weight.	Loss in Inches.
			lbs. oz.	oz.	lbs. oz.	lbs. oz.	
Heavy loam,	Not stirred,	1	138 4.0	11.5	138 4.0	0 11.5	.25
		2	137 13.0	11.5	137 9.0	0 15.0	.33
	Stirred,	3	144 7.0	11.5	144 14.0	0 4.5	.10
		4	139 13.0	11.5	140 6.0	0 4.5	.10
Light loam,	Stirred,	5	148 6.5	11.5	148 13.5	0 4.5	.10
		6	149 11.5	11.5	150 2.5	0 4.5	.10
	Not stirred,	7	143 1.5	11.5	143 5.0	0 8.0	.18
		8	148 3.0	11.5	148 3.0	0 11.5	.25

* Including rainfall.

TABLE IV.

Details of Experiment from August 28th to August 31st.

		No.	Aug. 28th. Weight.	Water added.	Aug. 31st. Weight.	Loss in Weight.	Loss in Inches.
			lbs. oz.	oz.	lbs. oz.	lbs. oz.	
Heavy loam,	Not stirred,	1	138 4.0	9.0	137 9.5	1 3.5	.43
		2	137 9.0	9.0	136 15.0	1 3.0	.42
	Stirred,	3	144 14.0	9.0	144 7.0	1 0.0	.34
		4	140 6.0	9.0	139 13.0	1 2.0	.40
Light loam,	Stirred,	5	148 13.5	9.0	148 13.5	0 9.0	.20
		6	150 2.5	9.0	150 2.5	0 9.0	.20
	Not stirred,	7	143 5.0	9.0	142 10.5	1 3.5	.43
		8	148 3.0	9.0	147 8.0	1 4.0	.44

The following table contains the summary of the preceding ones, giving the actual loss by evaporation during the whole period of time:

TABLE V.

Loss by Evaporation from August 15th to August 31st.

CONDITION OF SURFACE.	IN POUNDS AND OUNCES.		IN INCHES.	
	Lot I. Heavy soil.	Lot II. Light soil.	Lot I. Heavy soil.	Lot II. Light soil.
	lbs. oz.	lbs. oz.	Inches.	Inches.
Not stirred,	4 13.0	3 5.0	1.69	1.16
Not stirred,	4 9.0	4 2.5	1.62	1.46
*Stirred two inches,	3 10.5	1 12.5	1.29	.62
*Stirred four inches,	3 8.0	2 3.0	1.23	.77

* Stirred every alternate day, unless prevented by rain.

The amounts of water the soil lost by evaporation are given in pounds and ounces, and in inches. The figures for pounds and ounces represent the weight of water lost by evaporation from each can. Allowance is made for the water which fell as rain and for that artificially added, but not for the very small amounts received from dew or absorbed from the atmosphere as hygroscopic moisture. The surface of each can was 78.5 square inches. One pound for this surface would correspond to one pound and thirteen ounces for one square foot, or forty tons per acre. In expressing the loss in inches, the term has been used with the same meaning as is customary in stating the amount of rainfall. One inch of rainfall means enough water falling in rain to cover the surface of the given locality to the depth of one inch. When it is stated here that the loss from evaporation was 1.69 inches, it is meant that the amount of water evaporated would have been sufficient to cover the bottom of the can or the surface of the soil in it to the depth of one and sixty-nine one-hundredths inches.

THE MEANING OF THE EXPERIMENT.

In the October bulletin of the Station these results and their bearing upon tillage were discussed at considerable length. It is not proposed to repeat here what was then said more than to call attention to the lesson which these experiments illustrate in regard to one value of surface tillage.

In dry weather water escapes from the upper layers of the soil in two ways. It is taken up by the roots of plants and exhaled through the leaves, and it evaporates from the surface by the action of sun and wind. The water which passes through the plant brings it sustenance, and is on this account most useful to the farmer. That which evaporates from the soil is so much lost to him.

In these experiments during the last half of August, although the weather was neither particularly warm nor dry, the heavy soil lost four-tenths of an inch less water, and the light soil six-tenths less by evaporation when stirred at the surface than when not stirred.

Hoeing and cultivating the land on which crops are growing permits nature to bring the stores of water to the roots of the plants, so that they may live and thrive upon it and the plant food it brings, but tends to prevent its passing into the air and thus being lost.

The substance of the lesson taught by these experiments may be summed up in a few words from the October Bulletin:

"It is not simply for the sake of killing weeds that the farmer hoes his corn. Weeds are his enemies, but drouth is worse; and the moisture is often insufficient for full yield even when no drouth is apparent. The soil has reserve stores of water for his crops, but in summer the supply gets low, and the same force of capillarity which brings it up to where the roots of his plants can get it, carries it past them to the surface, where the sun's heat changes it to vapor, and winds bear it away. Hoeing and cultivating loosen the upper layer of the soil. The pores through which the water is drawn up are thus enlarged and the connection between them is broken; capillary action is consequently hindered and less water passes through. At the same time more air enters, and the loosened layer conducts less heat to the soil beneath. The loosened layer acts as a mulch, and tends to keep the soil below cooler while it prevents the water from reaching the surface, and thus, in a twofold manner, protects the rising moisture from evaporation. In this way the wise cultivator uses the forces of nature to bring water to the roots of his plants and at the same time to prevent its passing by them and escaping into the air. The water is freighted with plant food — part of it brought from below, part of it dissolved from the soil about the roots, and part derived from the air above. So the crops are nourished and the yield of the land increased."

ROOTS OF PLANTS AS MANURE.

BY CHAS. D. WOODS.

In 1878, in the laboratory of Wesleyan University, which was then, as now, in charge of the Director of this Station, several analyses of roots of wheat, timothy, and clover, were made by Mr. W. H. Jordan, now Director of the Maine State College Agricultural Experiment Station, and by the present Chemist of this Station. The results of these analyses were published in the Report of the Connecticut Board of Agriculture for 1878, as a part of the report of the Middletown Station. These results have been supplemented during the present year by analyzing all that is left in the field after crops have been removed, including stubble as well as roots. For this purpose crops grown upon the Storrs School farm were used.

Description of the specimens and results of the observations and analyses follow. For the sake of comparison, the old work is combined with the new. Numbers M. 7, 8, 9, 18, and 20, were analyzed by the Middletown station, as stated above. Numbers M. 29, 30, 32, 33, and 34, are the work of this Station.

METHODS OF OBTAINING SPECIMENS.

The specimens of roots and stubble for analysis were obtained from portions of the field representing, as nearly as could be determined, an average condition of the crop grown. After removing weeds and other foreign matter, a trench about two feet deep and large enough for convenience in working, was dug on all sides of a small section of earth, leaving a square block in the center a little more than two feet on a side.

The sides of this earth block were carefully trimmed until it was exactly two feet square, thus making an area of four square feet, or 1/10890 of an acre. By means of a cord drawn tightly around the block, sections six inches in depth were marked off and the earth from each layer removed into separate boxes. The trench was deepened as required for convenience in working as layers were removed.

Each section of the earth was worked over separately by hand labor, the roots, stubble (and in the case of the grass, the new growth), being separated from the soil and from the roots of weeds as far as possible. The fine, hair-like roots could not all be secured, but these represent so small a portion of the whole, that the results could not have been materially affected.

On the whole the method of obtaining the specimens and separating the roots, although laborious and time-consuming, was quite satisfactory. Had water been used to wash away the earth, a much larger portion of the finest roots would have been lost, as was shown by a number of preliminary trials in the earlier experiments.

In the earlier work of the Middletown Station the specimens were procured in essentially the same way, except the area examined was one foot by two, instead of two feet square.

The later specimens were obtained by the Vice-Director, and the assistant in the farm experiments, with the aid of the students of the senior class of the Storrs School.

DESCRIPTION OF SPECIMENS.

M. 7. *Timothy Roots.*—Specimens from farm of the Maine State College. Soil, clayey loam, heavy and wet, but under-drained. Surface soil six inches in depth. Subsoil, clay hardpan, with occasional stones. Roots and crop from an area of two square feet, weighed * as follows:

Roots from first 6 in.,	45.2 grams, or	2,170 lbs. per acre.
" " second 6 in. (6-12 in.),	5.7 grams, or	274 lbs. per acre.
" " third 6 in. (12-18 in.),	1.2 grams, or	58 lbs. per acre.
" " fourth 6 in. (18-24 in.),	0.3 grams, or	14 lbs. per acre.
" " first 2 feet,	52.4 grams, or	2,516 lbs. per acre.
Tops from this section,	104.7 grams, or	5,027 lbs. per acre.

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* Weights are air-dry, unless otherwise stated.

M. 8. *Wheat Roots.* — Specimens from same farm as M. 7. Soil, clay loam. Subsoil, heavy clay. A small growth of weeds made it difficult to distinguish accurately the wheat roots in all cases. Roots, crop, and stubble, from an area of two square feet, weighed as follows:

Roots from surface soil (0-12 in.),	12.3 grams, or	590 lbs. per acre.
" " subsoil, (12-21 in.),	2.6 grams, or	125 lbs. per acre.
Roots to depth of 21 in.,	14.9 grams, or	715 lbs. per acre.
Stubble from this section,	12.4 grams, or	595 lbs. per acre.
Tops " " "	147.7 grams, or	7,092 lbs. per acre.

M. 9. *Clover Roots.* — From same farm as M. 7 and 8. Soil, poor loam; clayey rather than sandy. Surface soil eight inches in depth. Subsoil, hardpan; quite pure clay. Roots and stubble, from an area of two square feet, weighed as follows:

Roots from surface soil,	28.9 grams, or	1,387 lbs. per acre.
" " subsoil,	1.5 grams, or	72 lbs. per acre.
Total roots from this section,	30.4 grams, or	1,459 lbs. per acre.
Stubble from this section,	26.5 grams, or	1,272 lbs. per acre.

M. 18. *Timothy Roots.* *M.* 20. *Native Grasses* (*pasture*). — These specimens were taken from adjoining lots of low, moist land upon the farm of Mr. J. M. Hubbard, Middletown. Soil, reddish or brownish sandy loam. The timothy was newly seeded. The native grass had been in for some years.

M. 29. *Cow Peas, Roots and Stubble.* — From School farm. The surface soil, to a depth of about seven inches, was a slight loam. Subsoil, yellow and compact; becoming, at a depth of thirty inches, loose and gravelly in texture. The specimen consisted of stubble and such roots as could be pulled out of the soil with the stubble. This included nearly all of the larger roots of the surface soil. This specimen is from three sections, of four square feet each, from a portion of the field which yielded 15,840 pounds of green crop per acre. Weight of specimen, after partial drying in the laboratory, 93 grams, or at the rate of 4,460 pounds per acre.

Crop harvested September 27th and 28th. Specimen taken October 3d.

M. 30. *Cow Peas, Stubble and Roots.* — From same field as M. 29. When received the specimen, from an area of four square feet, weighed as follows:

Stubble and first 6 in. of roots,	38.0 grams, or	912 lbs. per acre.
Second 6 in. of roots (6 12 in.),	1.87 grams, or	45 lbs. per acre.
Third 6 in. of roots (12-18 in.),	2.25 grams, or	54 lbs. per acre.
Fourth 6 in. of roots (18-24 in.),	1.43 grams, or	34 lbs. per acre.
Fifth 6 in. of roots (24-30 in.),	2.62 grams, or	63 lbs. per acre.
Sixth 6 in. of roots (30-36 in.),	2.47 grams, or	59 lbs. per acre.
Seventh 6 in. of roots (36 42 in.),	1.67 grams, or	40 lbs. per acre.
Stubble and total roots (0.42 in.),	50.31 grams, or	1,207 lbs. per acre.
After partial drying total weight was,	47.89 grams, or	1,150 lbs. per acre.

M. 32. *Timothy and Redtop, Stubble and Roots.* — Soil same as M. 29. Field was mowed July 23d, and yielded about two tons of hay per acre. At the time of collection of specimen the field contained, in addition to the roots and stubble, the rowen, or second growth, which was about three inches high, and was green and luxuriant. The crop was principally timothy, with a slight mixture of redtop. The specimen was taken November 7th from an area of four square feet, and weighed as follows:

Stubble (including rowen) and first 6 in. of roots, 330.9 grams, corresponding to 7,944 lbs. per acre.

M. 33. *Timothy and Redtop Roots.* — Soil as in M. 29. Specimen consisted of roots below a depth of six inches from from same section as M. 32. Sample taken November 7th, and weighed as follows:

Roots from second 6 in. (6-12 in.),	15.00 grams, or	360 lbs. per acre.
" " third 6 in. (12-18 in.),	9.00 grams, or	216 lbs. per acre.
" " fourth 6 in. (18-24 in.),	3.00 grams, or	72 lbs. per acre.
" " fifth 6 in. (24-30 in.),	1.00 grams, or	24 lbs. per acre.
" " sixth 6 in. (30 36 in.),	0.25 grams, or	6 lbs. per acre.
" " 6 to 36 in. in depth,	28.25 grams, or	678 lbs. per acre.
Weight of roots after partial drying,	27.00 grams, or	648 lbs. per acre.

M. 34. *Buckwheat, Stubble and Roots.* — Soil a compact clay loam, with rather more than average amount of vegetable matter. Subsoil, clayey, compact, and moist. Grown on the farm of the Storrs School. Buckwheat was cut September 24th. Roots collected September 29th. Specimen from an area of four square feet weighed as follows:

Stubble and roots from first 6 in.,	20.96 grams, or	503 lbs. per acre.
Roots from second 6 in. (6-12 in.),	0.85 grams, or	20 lbs. per acre.
Stubble and roots from first 12 in.,	21.81 grams, or	523 lbs. per acre.
Weight after partial drying,	21.00 grams, or	504 lbs. per acre.

The third six inches was practically free from roots.

Table VI that follows, is taken from the report of the earlier work referred to, and gives the result of some observations made at that time on roots of different plants.

TABLE VI.

Tabulation of Some of the Results of Observations on Roots of Different Agricultural Plants. Surface Area in Each Case Two Square Feet.

KIND OF PLANT.	TOPS.						ROOTS.								SOIL.						WEEDS AND REFUSE MATTERS.	
	Date of cutting.	Stage of growth at cutting.	Average height in inches.	Green weight, grams.	Dry weight, grams.[10]	Weight of stubble, grams.[10]	WEIGHT OF ROOTS OF SURFACE SOIL.[10]				Wg't of roots of subsoil.[10]	Total weight of roots, grams.[10]	Depth to which roots were traced.		Depth of surface soil.		Depth of subsoil, weight.		Total weight of surface soil.	Total weight of subsoil.	Weight of stubble and roots of weeds in soil and subsoil.	Weight of refuse organic matter.[3]
							Roots of first six inches.		Roots of second six inches.	Total roots of surface soil.												
							Known.	Supposed.														
			in.	grm	grm.	grm.	grm.	grm	grm	grm.	grm	grm.	ft.	in.	ft.	in.			lbs.	lbs.	grm.	
Clover, A,	July 14,	In full blossom,	...	115.0	34.5	.....	......	....	....	17.7	1.0	18.1	3	2	..	8½	..	..	132	....	....	......
" B,	Aug. 4,	Ripe,	...	...	.....	26.5	.....	. .	....	28.9	1.5	30.4	..	...	..	...	..	..	...	219	[4]6.0	......
Wheat, A 1,	July 17,	Just before heading,	24	190.7	53.2	4.7	[6]6.2	[6]4 9	...	11.1	1.2	12.2	..	...	..	8	1	6	103	157	3 9	14 9
" " 2,	" 27,	" blossoming,	33	270.8	93.5	8.2	[7]10.00	...	....	.....	[8]6.7	16.7	..	...	..	8	1	4	109	131	3.3	6.5
" " 3,	Aug. 9,	Seed in milk,	37	271.3	112.7	8.7	[9]8.75	[9]5.7	....	14.4	0.9	15.3	..	...	1	...		8	149	161	10.4	6.7
" " 4,	" 25,	" ripe,	39	206.2	147.7	12.4	8.3	4.0	....	12.3	0.5	14.9	..	...	1	...	.	9	190	...	8.9	......
Oats,	....	....	....	.....	104.9	4.5	......	....	....	5.1	1.0	6.1	..	.	.	...	..	..	159	180	9.8	......
Barley, A 1,	July 28,	Just before heading,	22	175 3	51.0	3.9	[9]3.5	[9]4.2	....	7.7	0.8	8.5	..	.	1	...	1	.	162	177	5.0	4.3
" " 2,	Aug. 9,	Commencing to blossom,	32	286.0	82.0	8.5	[9]5.6	[9]2.8	....	8.4	0.4	8.8	.	.	1	...	1		179	....	6.6	2.5
" " 3,	" 18,	Seed in milk,	32	322.2	102.2	10.6	4 77	1.8	2 5	9.1	0 7	9.8	..	...	1	.	1		166	190	12 8	......
" " 4,	" 31,	" ripe,	....	269.4	149.0	7 4	3.4	1.1	1.7	6.1	0.9	7.0	..	.	1	...	1	..	168	....	15.6	. ..
Hungarian,	" 31,	Nearly ripe,	....	312.8	129.1	7.1	9.5	....	4 1	13.5	1.5	15 0		...	...	...	..	..	....	...	3.3	......
Timothy, A,	July 13,	In full blossom,	..	196.3	88 5	.....	..	...	....	17.8	....	17.8	.	.	..	11	..	.	158	...	....	......
" B,	Aug. 9,	Ripe,	...	193.0	104.7	...	45 2	...	5.7	[5]52.1	0.3	52.4	2	4	1	5	.	.	253	....	17.4	. ....
" C,	" 9,	"	....	.....	109.4	42.6	......	....	....	108.5	0.1	108.6	..	...	1	3	..	..	130	....	....	......
" meadow, D,	....	....	....	.....	.....	64.6	.....	....	....	41.7	1.2	42.9	..	...	...	...	.	..	....	....	....	......
Native grasses, pasture E,	....	....	....	.....	.....	45 1	......	....	....	64.3	1 0	65.3	..	...	..	..	.		...	....	....	......
" " meadow, F,	....	....	....	.....	.....	72.1	......	....	...	85.6	1.7	87.5	3	10	..	...		..	....	....	....	......

NOTES. [1] As above stated it was difficult to distinguish accurately between the roots of the plants and those of weeds. [2] Where the line of demarcation between surface soil and subsoil was plain, its depth was taken for that of the surface soil, but where this was not the case the first twelve inches is called surface soil. [3] Includes fragments of leaves, stems, etc., found on surface of soil. [4] Mostly timothy roots. [5] Includes 1.2 grams roots taken from 12.17 inches in depth. [6] From first twelve inches. [7] Total surface soil. [8] Supposed wheat roots from soil, and subsoil. [9] From first twelve inches. [10] Air dry.

The following figures, obtained from Table VI, give the quantities of roots found at different depths. By surface soil is to be understood the layer which showed in its appearance the effects of tillage, and action of air and frost.

TABLE VII.

Weight of Roots and Stubble in One Acre.

KIND OF PLANT AND STAGE OF GROWTH.	Depth of Surface Soil.	Weight of Roots of Surface Soil.	Weight of Roots of Subsoil.	Weight of Stubble.	Weight of Roots and Stubble.	Weight of Tops (Crop).
Clover. In full blossom,.........	8	850	48	...	....	1657
Clover. Ripe,...	..	1388	72	1272	2732	....
Wheat. Just before heading,.....	8	533	58	226	817	2554
Wheat. Just before blossoming,..	8	480	322	394	1196	4489
Wheat. Seed in milk,...........	12	691	43	418	1152	5411
Wheat. Seed ripe,..............	12	591	125	595	131	7092
Oats,...........................	..	245	48	216	509	5037
Barley. Just before heading,......	12	370	38	187	595	2449
Barley. Commencing to blossom,	12	403	19	408	830	3937
Barley. Seed in milk, ...	12	437	34	509	980	4907
Barley. Seed ripe, ...	12	293	43	355	691	7154
Hungarian,.......................	..	648	72	341	1061	6199
Timothy. In full blossom,.......	11	855	..	...	....	4249
Timothy. Ripe,..................	17	2502	14	...	....	5027
Timothy. Ripe,..................	15	5210	5	2056	7271	5254
Timothy. From meadow, ...	..	2002	58	3102	5162	....
Native Grasses. Pasture, ...	..	3087	48	2166	5301	....
Native Grasses. Meadow,........	..	4110	82	3462	7654	....

METHODS OF ANALYSIS.

Preparation of Sample.—The samples were freed as completely as possible from adhering particles of soil. In order that the sample might be easily ground, they were dried for some hours at 100° C, exposed to the air over night, weighed, and then ground so as to pass through round holes $\frac{1}{2}$ m. m. in diameter.

Water.—The substance was dried at 100° C, to constant weight.

Nitrogen.—In M. 7, 8, 9, 18, and 20, nitrogen was determined by soda lime; in M. 29, 30, 32, 33, and 34, by the Kjeldahl method.

Crude Ash. — The crude ash was obtained by charing in platinum dishes at a faint red heat, extracting the residue with water, strongly igniting the insoluble portion, then adding the water extract, evaporating the whole to dryness, and heating to faint redness till the ash was as white as it was before the addition of the extract.

Carbon dioxide.— In M. 7, 8, 9, 18, and 20, carbon dioxide was determined by igniting with potassium dichromate; in M. 29, 30, 32, 33, and 34, it was expelled by hot nitric acid and absorbed by potassium hydroxide.

Insoluble residue. — The amount of insoluble matter in M. 7, 8, 9, 18, and 20, was found by extracting the crude ash with hot aqua regia and then with a mixture of sodium carbonate and hydroxide; in 29, 30, 32, 33, and 34, the treatment with the alkalies was omitted.

Pure Ash. — The per cent. of carbon dioxide and the per cent. of insoluble residue in crude ash, subtracted from the per cent. crude ash, gives per cent. of pure ash in crude ash. The per cent. of crude ash in water-free substance multiplied by per cent. of pure ash equals per cent. of pure ash in water-free substance.

Phosphoric acid. — The aqua regia solutions obtained in making insoluble residues were evaporated to dryness, with excess of nitric acid to expel chlorine, and then moistened with concentrated nitric acid and extracted with water. In these solutions the phosphoric acid was determined by the ammonium molybdate method.

Potash. — The aqua regia solutions obtained in making insoluble residues were evaporated to complete dryness to render the silica insoluble, moistened with strong hydrochloric acid, and extracted with water. In these solutions the potash was determined by the use of platinic chloride. In the earlier work the method recommended in Caldwell's Agricultural Chemical Analysis, section 44, c, was employed; in the later work, the "Official Method," as adopted by the Association of Official Agricultural Chemists in 1887.

RESULT OF ANALYSIS IN TABULAR FORM.

Table VIII shows the percentages of water, water-free or dry substance, crude ash, organic mater, and nitrogen in the specimens. The percentages of water show the actual water in the roots not as collected but after partial drying, and are of value only as they make it possible to calculate the results of analyses to dry substance. In the last three columns the percentages are calculated upon water-free, i. e., dry substance. The organic matters represent the loss in combustion, the mineral matters remaining behind to form crude ash.

TABLE VIII.

Composition of Roots and Stubble.

KIND OF PLANT AND PORTION ANALYZED.	Laboratory number.	IN AIR DRY SUBSTANCE.		IN WATER-FREE SUBSTANCE.		
		Water.	Water-free substance.	Crude ash.	Organic matter.	Nitrogen.
		p. c	p. c.	p. c.	p. c.	p. c.
Timothy, roots,	M 7	10.97	89.03	10.99	89.01	1.39
Wheat, roots,	M 8	8.04	91 96	19.93	80.07	.98
Clover, roots,	M 9	8 64	91.36	9.79	90.21	2.66
Native grass, pasture, roots,	M 18	6.63	93.37	21.35	78.65	1.20
Timothy, roots,	M 20	7.64	92.36	15 05	84 95	1.26
Cow peas, stubble and roots to depth of 6 in.,	M 29	4.38	95.62	6.31	93 69	1.40
Cow peas, stubble and roots to depth of 3½ ft.,	M 30	4.82	95.18	22 29	77 71	1 32
Timothy and redtop, stubble and roots to depth of 6 in.,	M 32	4.27	95.73	17.64	82 36	1 10
Timothy and redtop, roots below 6 in. to depth of 3 ft.,	M 33	4 80	95.20	32 41	67 59	1.04
Buckwheat, stubble and roots to depth of 1 ft.,	M 34	4.46	95.54	24.58	75 42	.91

In the first two columns of Table IX, which follows, are given the percentages of carbon dioxide ("carbonic acid gas") and insoluble residue in crude ash. Subtracting the sum of these two from 100 per cent. gives the percentage of pure ash in crude ash. In the last two columns the percentages of phosphoric acid and potash are given as calculated to pure ash. They show how variable the amounts of these substances are even when the ash is freed from foreign matters. Perhaps the most striking fact brought out by this table is that the amounts of potash and phosphoric acid present in the pure ash of stubble are so much larger than in that of the roots. Of the two specimens of cow peas, the first has a relatively small amount of roots, and consists largely of stubble, and yet it has one-half more of these valuable ingredients than the second specimen, which, in addition to the stubble, has the roots to the depth of three and one-half feet. The same thing is more strikingly shown in the specimen of timothy stubble and first six inches of roots, as compared with the specimen consisting wholly of roots. Here the percentage of phosphoric acid is nearly twice and the potash three times as great in stubble and roots as it is in the roots alone.

TABLE IX.

Composition of Ash of Roots and Stubble.

KIND OF PLANT AND PORTION ANALYZED.	Laboratory number.	IN CRUDE ASH.			IN PURE ASH.	
		Carbon dioxide, CO_2.	Insoluble residue.	Pure ash.	Phosphoric acid, P_2O_5.	Potash, K_2O.
		p. c.	p. c.	p. c.	p. c·	p c.
Timothy, roots,..	M 7	6.72	32.75	60.53	4·72	5 62
Wheat, roots,	M 8	1.77	61.57	36.66	3.20	5 46
Clover, roots,.	M 9	9.49	26.08	64.43	11.95	17 91
Native grass, pasture, roots,.	M 18	8 90	61.89	29 21	5.51	4.07
Timothy, roots,..	M 20	8 26	50.52	41.22	4.51	3.13
Cow peas, stubble and roots to depth of 6 in ,.	M 29	3.85	30.70	65.45	9.27	18 37
Cow Peas, stubble and roots to depth of 3½ ft.,.	M 30	.68	77.30	22.02	5.22	11.88
Timothy and redtop, stubble and roots to depth of 6 in.,.	M 32	.89	74.73	24.38	7.28	16.35
Timothy and redtop, roots below six inches to depth of 3 ft ,.	M 33	.70	82.10	17.20	4 17	6.62
Buckwheat, stubble and roots to depth of 1 ft.,.	M 34	3.31	71.01	25.59	4 32	12.80

In Table X following this, the first column gives the weight of the air-dry roots and stubble as obtained from the several sections. In the first three specimens the actual section was two square feet; in the last five the area was four square feet. The figures for the former are doubled so as to make them comparable with the latter. Weights are expressed in grams. In the last three columns are given weights of roots and stubble, crude ash, and organic matter in one acre. The large amount of stubble and roots left by the timothy are very striking, and the added value of the stubble is shown in the difference between the weight of roots in M. 7 and the stubble plus roots in M. 32.

TABLE X.

Amount of Dry Roots and Stubble, Ash, and Organic Matter in one Acre.

KIND OF PLANT AND PORTION ANALYZED.	Laboratory number.	IN FOUR SQ. FEET.		IN ONE ACRE.		
		Air dry root, etc.	Water-free roots, etc.	Water-free roots, etc.	Crude ash.	Organic matter.
		grs.	grs.	lbs.	lbs.	lbs.
Timothy, roots,.......	M 7	104.8	93.3	2,240	246	1,994
Wheat, roots,....................................	M 8	29.8	27.4	658	131	527
Clover, roots,...................................	M 9	60.8	55.6	1,335	131	1,204
Cow peas, stubble and roots to the depth of 6 in.,..	M 29	31.0	29.6	711	45	666
Cow peas, stubble and roots to depth of 3½ ft.,.....	M 30	47 9	45.6	1,095	244	851
Timothy and redtop, stubble and roots to depth of 6 in.,...	M 32	330.9	316.8	7,606	1,342	6,264
Timothy and redtop, roots below 6 in. to depth of 3 ft.,..	M 33	27.0	25.7	617	200	417
Timothy and redtop, stubble and total roots, M 32 and 33 combined,............................	......	357.9	342 5	8,223	1,542	6,681
Buckwheat, stubble and roots to depth of 1 ft.,.....	M 34	21.0	20.1	483	119	364

Table XI gives the pounds of pure ash, nitrogen, phosphoric acid, and potash in one acre.

TABLE XI.

Amounts of Most Important Ingredients of Plant-food in One Acre.

KIND OF PLANT AND PORTION ANALYZED.	Laboratory number.	IN ONE ACRE.			
		Pure ash.	Nitrogen.	Phosphoric acid, P_2O_5.	Potash, K_2O.
		lbs.	lbs.	lbs.	lbs
Timothy, roots,	M 7	149	31.1	7.0	8.4
Wheat, roots,	M 8	48	6 4	1.5	2.6
Clover, roots,	M 9	84	35.5	10.0	15.0
Cow peas, stubble and roots to the depth of 6 in.,	M 29	29	10.0	2 7	5.3
Cow peas, stubble and roots to the depth of 3½ ft.,	M 30	54	14.5	2.8	6 4
Timothy and redtop, stubble and roots to the depth of 6 in.,	M 32	327	83.7	23.8	53.5
Timothy and redtop, roots below 6 in. to depth of 3 ft.,	M 33	34	6.4	1.4	2 3
Timothy and redtop, stubble and total roots, M 32 and 33 combined,	......	361	90 1	25.2	55.8
Buckwheat, stubble and roots to depth of 1 ft.,	M 34	30	4.4	1.3	3.8

FERTILIZING MATERIALS IN ROOTS.

The manurial value of roots depends upon both their composition and quantity. The most valuable ingredients are nitrogen, phosphoric acid, and potash. The following table gives the weight of roots (or roots and stubble), and of the ingredients per acre in the experiments named, and with them corresponding results of observations made by Dr. Voelker in England, and Dr. Weiske in Germany.

TABLE XII.

Amount of Roots and Stubble and Valuable Ingredients left in one Acre, with Valuable Ingredients in Manures.

KIND OF PLANT AND PORTION ANALYZED.	Roots and Stubble.	Nitrogen.	Phosphoric Acid.	Potash.
	LBS.	LBS.	LBS.	LBS.
Reported herewith.	Water free.*			
Cow peas. Stubble and roots to depth of 6 in.	711	10.0	2.7	5.3
Cow peas. Stubble and roots to depth of 3½ ft.	1095	14.5	2.8	6.4
Timothy and redtop. Stubble and roots to depth of 6 in.,	7606	83.7	23.8	53.5
Timothy and redtop. Roots below 6 in. to depth of 3 feet,	617	6.4	1.4	2.3
Timothy and redtop. Stubble and total roots to depth of 3 feet,	8223	90.1	25.2	55.8
Buckwheat. Stubble and roots to depth of 1 foot,	483	4.4	1.3	3.8
Middletown Station (W. O. Atwater).				
Timothy. Roots,	2240	31.1	7.0	8.4
Wheat. Roots,	658	6.4	1.5	2.6
Clover. Roots	1335	35.5	10.0	15.0
Dr. Voelker, England.				
"Good Clover." First year. Roots,	4155	100.0	....	....
"Bad Clover." First year. Roots,	1550	31.0	....	....
"Thin Clover." Second year. Roots,	7026	66.0	29.5	....
"Good Clover." Second year. Roots,	6503	65.0	27.0	....
Clover. First year. Mown twice. Roots,	1493	24.5	....	....
Clover. First year. Mown once. Roots,	3622	51.5	....	....
Dr. Wieske, Germany.	Air dry.			
Rye. Roots and Stubble,	3400	62.0	24.0	30.0
Barley. Roots and Stubble,	1515	22.0	11.0	9.0
Oats. Roots and Stubble,	2200	25.0	28.0	24.0
Wheat. Roots and Stubble,	2240	22.0	11.0	17.0
Red clover. Roots and Stubble,	6580	180.0	71.0	77.0
Buckwheat. Roots and Stubble,	1630	45.0	10.0	9.0
Peas. Roots and Stubble,	2400	53.0	14.0	11.0
Lupine. Roots and Stubble,	2800	58.0	13.0	16.0
Fertilizers.	Fertilizers. LBS.			
Rich stable manure,*	2000	10	10	8
Nitrate of soda,	100	16	..	..
Dissolved bone black,	100	..	16	..
Ground bone,*	100	3	22	..
Muriate of potash,	100	..	..	50

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* Analyses taken from Farmers' Annual, 1882, Jenkins and Armsby.

When the stubble is turned under, both it and the roots decompose and their manurial ingredients become more or less speedily and completely available for succeeding crops. The crop that leaves a large amount of these materials in and upon the soil after harvesting adds much to the next year's store of plant-food and hence to the fertility of the soil.

In the few cases in which the stubble was weighed, it was nearly as much as the roots of the first six inches of the soil. Of course the amount of stubble would vary much with the manner of harvesting the crop. In the case of such plants as grass, a new growth starts after the crop is removed and increases with the length of time between harvesting and plowing under.

As might be expected, the amount of roots and stubble vary with different crops and even with the same kind of crop under different circumstances. The ratio between the amounts of roots and of tops is extremely variable, still it is safe to say in general that the greater the amount of the crop of a given plant the greater will be the amount of roots and stubble left behind. But a small crop of one plant, as clover, may leave more fertilizing material in the soil than a large one of another plant like wheat. These facts, together with the small amount of roots worked upon, tend to make uncertain many lessons that might be drawn from these tables (indeed perhaps the most important fact here brought out is the need of more observations), still certain general conclusions must be true.

PRACTICAL CONCLUSIONS.

Clover roots and stubble contain large percentages of the three most valuable ingredients of plant-food, nitrogen, phosphoric acid, and potash, and as clover leaves a large amount of roots and stubble in and upon the soil, it adds greatly to the store of fertilizing material for future use. As will be seen from the table, Dr. Weiske found a little over three tons of stubble and roots per acre remaining from a crop of clover. This contained 180 lbs. of nitrogen, 71 lbs. phosphoric acid, and 77 lbs. of potash. From the composition of fertilizers as given in the above table, it would require over 1,100 lbs. of nitrate of soda, 400 lbs. of dissolved bone black, and 150 lbs. of muriate of potash to furnish the same amount of fertilizing materials. It should be borne in mind, however, that in such fertilizers as nitrate of soda and superphosphate the plant-food is ready for use at once. In roots and stubble, as in stable manure, chemical changes are first needed to make the ingredients available to the plants that feed on them. Hence a pound of nitrogen may be worth more in nitrate of soda than in roots or stable manure, because it brings a quicker return in the crop.

While the cow pea in these experiments did not leave as much per acre as the clover, yet it furnishes a very considerable amount of valuable manure. The crop from which these samples were taken was small, and probably in most cases more plant-food would be left for the next crop than this experiment would indicate.

The timothy stubble and roots together, while not having as large percentages of the valuable ingredients of plant-food as clover, yet with the great amount of stubble and new growth that is plowed under, yields a great deal of manurial matter. This may explain why crops do so well when planted upon turf. An illustration occurred in one of the field experiments conducted for the station during last season. The field selected for the experiment was covered with a heavy sod at the time of plowing. The plots to which no manure was applied yielded at the rate of over fifty bushels of shelled corn to the acre. Part of the plant-food that made this possible came from previous manuring, but doubtless a great deal of it was supplied by the roots and stubble.

So far as it is safe to judge from the figures contained in the table, wheat, oats, and buckwheat leave much less plant-food in the soil than the other crops. Probably the grain crops as a class are of comparatively little value in enriching the soil for following crops.

Clover, cow peas, and other legumes have a peculiar power of gathering plant-food, and especially nitrogen, from natural sources. Although they contain much more nitrogen than wheat, oats, and similar grains, they thrive and bring large yields where wheat will not. While their especial faculty for gathering nitrogen from the stores in the soil and probably from the air is not yet explained, the important fact here is that they do gather it and leave a great deal of it in the roots and stubble. Nitrogen is the costliest ingredient of fertilizers. These facts help to explain the economy of clover for manure, and why clover is so valuable as a preparatory crop for wheat and other grains.

The above-cited facts would seem to imply that the legumes, such as clover, are especially valuable for this kind of manuring; that timothy and other grasses stand next; and that the grain crops leave the least amounts of plant-food in roots and stubble.

METEOROLOGICAL OBSERVATIONS.

C. S. PHELPS.

The importance of meteorological data in connection with other work of Experiment Stations is apparent to all. Differences in season constitute a serious disturbing element in field experiments. Conclusions drawn from such experiments are much more firmly grounded when the rainfall and its distribution, the temperature and humidity of the atmosphere, and the percentages of clear and cloudy weather, have been duly considered. The season stands next to the soil in its influence on the production of farm crops. The weather therefore, constitutes an important factor in all field experiments.

The value of these observations depends first on the accuracy of the instruments used and the regularity and care exercised in their use, and secondly on the number of years that the observations have been conducted. In order to obtain the more useful and necessary meteorological data the Station has been equipped with the ordinary instruments for obtaining temperatures, humidity, rainfall, etc., uniform with those in use by the United States Signal Service.

Observations commenced June 1st with an outfit consisting of standard maximum, minimum, wet and dry bulb thermometers, Green's pattern, and the New England Meteorological Society's rain gauges. A Standard Signal Service barometer was added July 1st, and an anemometer with an electrical recorder has since been brought into use.

The thermometers and barometer are placed in a small thermometer house, especially constructed for the purpose, with sides and bottom of open shutters and lattice; the roof double, and insulated by a dead air space and by asbestos paper beneath the shingles. The whole is firmly set two and one-half feet above the ground, and a sufficient distance from any building or tree to allow free exposure to all points of the compass.

Three times daily, at 7 A. M., 2 and 9 P. M., the temperature, pressure, relative humidity of the air, direction and force of wind, general state of the weather, and amount of rain, if any has fallen, are recorded. In addition to these observations, the maximum and minimum temperatures for the previous twenty-four hours are recorded at 9 P. M. The average of the tri-daily readings, with the 9 P. M. reading taken twice, is found to give very nearly the average temperature of the twenty-four hours. The average of the maximum and minimum correspond very closely to this, but it is not considered quite as accurate as the former method, for obtaining the daily mean. Monthly blanks furnished by the New England Meteorological Society are filled out at the close of each month, one copy being sent to the Society, and another put on file at the Station.

The importance of conducting observations in the immediate vicinity of experiment fields cannot be too strongly urged. At Canton, where one of the New England Meteorological Society's Stations is located, the rainfall for July was 3.14 inches, while at West Simsbury, about three miles in a direct line to the east, but with a mountain intervening, the fall for the same period was 2.33 inches, a difference of .81 inches.

During a portion of the summer the Station took observations of rainfall in the grass and forage garden about sixty rods from where the other observations were taken. The results were as follows:

	August.
Grass and Forage Garden, . . .	5.16 inches.
On hill near Laboratory, . . .	4.97 "

September 1st to 18th, inclusive:

Grass and Forage Garden, . . .	5.73 inches.
On hill near Laboratory, . . .	5.50 "

In the single storm of August 22d, there was a difference of .19 inches.

The peculiarities of the season were the cool and late spring, low temperature during the summer, early frosts, and the large amount of rainfall during the fall months. Quite severe frosts occurred as late as May 16th, and the first damaging frosts of the fall came September 7th, leaving a growing period of 114 days without injurious frosts. The average date in Massachusetts, for fifty years, for the last frost in the spring, was found to be May 16th, and for the first in the fall, September 20th,—leaving a period of 127 days.*

The rainfall during the last half of the year was considerably in excess of the average. In New England the yearly rainfall is about 44 inches. The fall at the Station from July 1st to December 31, 1888, was 31.92 inches or nearly 9 inches in excess of one-half the average annual rainfall.

Table XIII gives the results of observations on the amount of rainfall as obtained by gentlemen conducting experiments in connection with the Station, in various parts of the State. Table XIV summarizes observations made at the Station in Mansfield.

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* Third annual Report Massachusetts State Experiment Station.

TABLE XIII.

Rainfall during June, July, August, and September. Observations made at Thirteen Localities in the State.

LOCALITY.	OBSERVER.	RAINFALL IN INCHES.			
		June.	July.	Aug.	Sept.
Birmingham,	H. R. Stevens,	2.01	1.76	6.56	7.67
New Britain,	H. F. Wells,	1.27	2.01	4.66	7.95
Newington,	F. A. Kirkham,	1.20	1.75	4.91	8.31
West Simsbury,	S. T. Stockwell,	1.89	2.33	3.67	8.88
Durham,	H. S. Merwin,	*1.60	1.65	6.29	6.96
Middletown,	H. H. Hubbard,	2 04	1.45	6.74	7.47
Vernon Center,	E. H. Lathrop,	1.01	2.03	......	7.85
Mansfield,	E. A. Bailey,	2.10	1.93	4.97	8.45
Pomfret,	W. I. Bartholomew,	*1.60	1.89	6.29	8.95
South Woodstock,	L. J. Wells,	......	1.51	4.19	9.17
North Woodstock,	L. H. Healey,	......	3.30	3.73	9.24
Brooklyn,	H. F. Cox,	*1.60	2.46	7.35	9.04
Clark's Falls (N. Stonington),	J. B. Perry,	1.05	1.91	7.72	9.62

* Observations began June 10.

TABLE XIV.

METEOROLOGICAL SUMMARY.

June 1*st to December* 31*st. Observations made at the Station by E. A. Bailey.*

	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Highest barometer,	.....	30.29	30.28	30.65	30.50	30.86	30.49
Lowest barometer,	......	29.46	29.56	29.51	29.47	29.39	29.24
Mean barometer,	.....	30.00	29.97	30.07	29.95	30.12	30.01
Highest temperature,	94.2	86 9	87.6	74.5	65.4	69.0	56.9
Lowest temperature,	41.0	50.2	44.4	26.9	26.5	8.9	1.5
Mean temperature,	65.3	66.4	67.3	57.1	43.8	39.7	30.0
Relative humidity,	76.9	74.7	77.5	83.7	82.0	.....	.....
Total precipitation,	2.10	1.93	4.97	8.45	6.35	4.94	5.28
No. of days with precipitation of .01 inches or more,	10.	7.	9.	10.	15.	13.	6.
*No. cloudy days,	3.	4.	6.	10.	7.	11.	6.
*No. clear days,	5.	9.	10.	10.	5.	12.	7.

* Cloudy and clear at each observation (7 A. M., 2 and 9 P. M.)

CO-OPERATIVE FIELD EXPERIMENTS WITH FERTILIZERS.

BY C. S. PHELPS.

During the past season the Station instituted, in different parts of the State, a series of experiments with fertilizers. These have been conducted upon a variety of soils and in various localities; the aim being to have at least one experiment in each county. The object of these experiments is threefold.

(1.) To work directly upon farm-lands in different parts of the State and aid the owners in determining the deficiencies of their soils and the requirements of their crops.

(2.) To help practical farmers to become familiar with the more important fertilizing materials containing nitrogen, phosphoric acid, and potash, their action upon different soils and crops, and to encourage them to investigate for themselves the complicated questions involved in a rational and profitable use of fertilizers.

(3.) Thus to gradually develop a number of trained farm-experimenters, whose work will be useful not only to themselves, but in larger degree to their communities and to the agriculture of the State.

The work has been done as far as possible under the direct supervision and control of the Station. The experiments were all visited once, and most of them several times, by the Vice-Director; and in most cases the work of applying the fertilizer, planting, and weighing the crops, was under the immediate supervision of a representative of the Station.

The organization of the Station was not completed until the first week in April, 1888, and hence the arrangements for the field experiments were made somewhat hurriedly and the selections of soil and locality were not, in all cases, such as might have been secured if more time could have been allotted to the work.

The most serious obstacle met with in field experiments, and one which there is no means of detecting until the harvest returns are made, is found in the variations in the soil of the same field. To partially overcome this difficulty the Station proposes to select the more promising experiments of the past season and extend them through a series of years on the same soil, and with the same crop; or in some cases with a rotation of crops.

In connection with the greater part of these co-operative field experiments, records of the rainfall have been kept in close proximity to the fields, by the gentlemen upon whose farms the experiments were conducted. In most parts of the State the rainfall was sufficient to supply the full requirements of the crop. At Clark's Falls (North Stonington), however, the drouth through June and early July checked the growth, and interfered very materially with the development of the crop. In the southern part of Hartford County also, the drouth became moderately severe during the latter part of July. Dry pastures became parched, and the recently mown grass-fields failed to start a thrifty second crop; but the growth of corn was not materially checked. On the whole the season was a poor one for corn throughout all New England, and hence an unfortunate one for the success of this class of experiments. The spring was cold and late, quite severe frosts occurring as late as May 16th. The weather was cool during most of the summer, and early frosts, together with excessive rains, interfered with the maturing and drying of the crop. Severe frosts occurred as early as September 7th, making the season between damaging frosts only 114 days. The average period in Massachusetts for fifty years, between the last frost in the spring and first frost in the fall, has been found to be 127 days.

In another part of the report will be found the meteorological summary, and the rainfall as measured in thirteen localities in the State.

The following are the directions for conducting these experiments, as published in pamphlet form early in the season of 1888, and sent to all parties aiding in the work. They were prepared by the Director and are essentially the same as have been used for work of this sort in Connecticut and elsewhere in previous years.

GENERAL DIRECTIONS FOR THE EXPERIMENTS.

While the Station does all it can, by printed explanations and directions, and by the presence and help of its representatives, it especially requests the experimenter to bestow upon the experiments his most thoughtful attention and accurate work. It invites particular attention to the following directions :

" What is worth doing is worth doing well." In furtherance of the purpose of the experiment and its best execution, please note :

The "Condensed Directions."— This slip is intended to be taken into the field for use in laying out the experiment.

The Blank for Report— This will be furnished by the Station. Please look it over while the crop is growing, consider what it asks for, and make up your mind how to collect the facts. If ways of improving the plan occur to you, please suggest them, and if agreed to on consultation, adopt them, and at any rate accept thanks.

EVERYTHING IN ORDER BEFORE STARTING.

1. Have your plans complete and clearly in mind, and everything ready before you start. Proper plans at the outset; uniform soil for all the experiments; "worn-out" soil for the soil tests ; plots of proper size, shape, and accurately laid out ; right application of the fertilizers ; good seed ; careful measurement of crops ; full notes of detail ; and careful observation of the effects of the fertilizers on succeeding crops,—are essential to the best results.

CONVENIENCES.

2. It will be well to have at hand in planting, a small spring-balance and a light coal-hod or pail. With these it is easy to weigh out the fertilizers from the bags, divide the contents of each bag into portions, and carry these portions of the fertilizers to corresponding portions of the plot on which they can be spread. This will help greatly to uniform spreading.

At harvest you will need a scale and a bail-basket holding at least two or three pecks, to weigh the crop. The product on each plot can be divided, and weighed and measured in small portions. A small note-book will be needed to take into the field during the season and put down observations as made. From this you can copy all you wish to preserve in a more substantial book at your leisure.

UNIFORM SOIL.

3. The soil should be as nearly uniform in quality as possible. There will be more or less variation in different parts of the same field at best. The less there is of this, the more reliable will be the experiment. Level land should be chosen if practicable, but if it is sloping, let the plots run up and down the ascent, so that wash by rains will not transfer the materials from one plot to another. Of course the portion chosen for experiment should be a fair sample of the whole field.

"WORN-OUT" SOILS FOR SOIL TESTS.

4. Select "worn-out" soil. You want to learn what the soil itself can do by its own natural strength, not what it will do with the aid of a store of plant-food, which has been either accumulated by natural processes, or left over from previous manuring and will obscure the action of the fertilizers.

LAY OUT PLOTS ACCURATELY.

5. Lay out the whole experimental area and the individual plots as accurately as you can. Measure with chain or tape, if you have it, otherwise with pole marked in feet and inches. Drive good strong stakes firmly into the ground at the boundaries, so that you may be able to tell in this and coming seasons where the divisions are. There should be four stakes for each plot, one at each corner. These will show the boundaries of the plots, and of the unmanured space between them. The stakes for each plot can be marked with the number of the plot (A, B, C, etc., for the soil tests, and 1, 2, 3, etc., for the special nitrogen experiments). Cut the marks in the stakes with a knife. The tag on the bag can be tied to one of the stakes of the plot to which it belongs.

SIZE AND SHAPE OF PLOTS AND EXPERIMENTAL FIELD.

6. Generally speaking it is best to make the plots long and narrow, so as to compensate as far as possible for the unevenness of the soil. To this end let the whole area be as long and narrow

as convenient, and the plots run lengthwise through it. If the seed is to be planted in rows the length can be adapted to the distance of the rows apart. The "Condensed Directions" give figures which will help in calculating the dimensions of the plots and field.

If the soil is even, small, short plots will do. But generally it will not be even, and long strips are therefore safer.

In general, an unmanured strip at least two or three feet, and better, four feet, wide should be left between each two plots, so as to prevent the plants of one from being affected by the manure of another. In experiments with corn or potatoes these strips may be planted with potatoes. With other crops, as oats, it may be convenient to have them unmanured.*

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*The following is from a letter from Mr. W. I. Bartholomew, of Putnam, Conn., who is known as the maker of most accurate and useful experiments of this kind, on his own farm, during a long series of years. He formerly laid out his experiments with corn and potatoes, in plots very long, and only wide enough for two rows. He suggests, however, the desirability of making them wide enough for five rows. "There will be less proportionate robbing from adjoining plots, especially if the plots are not separated by intervening spaces. If they are so separated (as they should be) less ground will be occupied by these spaces, which are not reckoned in the test. If the plots are five rows (1 rod) wide, each rod in length (making a square rod) may be fertilized separately, and its crop harvested separately. The amount of produce of each, if recorded in a proper manner, would aid much in showing the variations in the field, if such should exist. Again, such irregularities as come in any rod from the loss of a few hills, or a rock or tree interfering, may be canceled by leaving out that rod from the test. The plots may be extended to 12, 16, 20, or any given number of rods, to suit the size or shape of the field, and yet be conveniently reckoned as so many one-hundred-and-sixtieths of an acre. To assist in carrying out the experiment, let the spaces between the plots be given to some other plants than the ones tested, and the same be done with one or more rows around the outside of the field. If desirable these intervening spaces may be fertilized in the hill.

"For convenience I would strongly recommend to mark out the rows as follows:

"*For Corn.*—Make five rows to the rod each way, that is $3\frac{3}{10}$ feet apart. This is a very convenient distance to cultivate, and it gives twenty-five hills to the square rod, and 4,000 hills to th acre. Of medium-sized corn, four stalks are enough to remain in a hill, or three stalks, if the corn is large. Stock the crop of each square rod by itself in the center of the square, and weigh the ears when husked.

"*For Potatoes.*—Make the rows same as above each way, but put an intervening hill lengthwise of the plot."

FERTILIZERS WELL DIFFUSED THROUGH SOIL.

7. The fertilizers may be applied broadcast, or if more convenient, they may be put in the hill or drill, *provided they are well diffused through the soil.* To accomplish this, they had better be diluted with several times their bulk of earth before using. The important points are, that they be :—

1st. Applied evenly over the plots where they belong, and not allowed to get outside.

2d. Well distributed through the soil.

Experiments with concentrated fertilizers are often spoiled, just as crops are injured or lost through wrong application. Farmers are apt to think the manure must be put close to the seed or the plant will not get the benefit of it. This is wrong. It is not the just germinated plantlet that needs the manure, but the plant, from the time it is well started until its growth is done. We want, not only to give the crop a good start, but to help it out on the home stretch as well. The roots and their branching rootlets run out in all directions in search of food, and the fertilizers ought to be where as many of the rootlets as possible can get at them. If we distribute the fertilizers as well as we can, the water in the soil, aided by the chemical and physical forces that nature keeps in operation, will do the rest. In illustration of this remember how well barn-manure acts when applied as a top-dressing long before the seed is put in.

But if we concentrate the fertilizers in one place fewer roots will get them, and these may be injured by coming in contact with them or with their concentrated solutions in the soil The roots will find their way to the manure and develop more where it lies, it is true, still we should not oblige them to huddle together in one place, but should rather encourage them to spread around, where, with the increased capacity the fertilizer gives them, they can get the more from the soil. Roots join with other natural agents in rendering inert stores of plant-food available.

Above all, do not let the fertilizers come too close to the seed. A coarse, dilute material like yard manure may do the plants no harm, but such concentrated fertilizers as potash salts, nitrate of soda, dried blood, or high grade superphosphates may kill them.

Since in these experiments it is particularly important that the effect of each fertilizer be fairly tested, it would be well to *mix* *them with three or four times their bulk of mellow earth before applying.* Moist sawdust may be used in place of the earth, if more convenient. Do this by all means if applied in the hill or drill. It will be well to even off the ground by a shallow plowing, spread the fertilizers evenly over the plots, and then work them in with a good deep-running harrow, or turn them under by very shallow plowing. When the plots are accurately staked out and the fertilizers carefully applied and worked in, the plow or harrow may be run across the plots without fear of transporting the fertilizers from one to another. Apply some days before planting if practicable.

As to applying the fertilizers broadcast in the hill, and the need of mixing them with earth before applying, Mr. Bartholomew gives the following as the result of his experience:

"Where the quantity of fertilizer is as small as 320 lbs. to the acre (2 lbs. per square rod) I would scatter it evenly about the hill to a distance of say ten or twelve inches from the center of the hill. If so small an amount were spread over the whole surface I think the young plants would not get enough nourishment early in the season, especially on poor soil. But with the larger quantities, and particularly with the fertilizers containing potash salts, and nitrate of soda or other forms of nitrogen, it is well to apply broadcast. When the materials are spread over the surface it is not necessary to previously mix them with earth. But when the experimenters put the fertilizer in large quantities in the hill or drill, as some doubtless will do, it should be mixed with dry earth and scratched in with an iron rake or well covered. *Don't let the seed come in contact with nitrogen or potash fertilizers.*"

UNMANURED PLOTS FOR COMPARISON.

8. It is of the greatest importance that several unmanured plots be left for comparison. For eight manured plots, two unmanured willl suffice; but where there are more than that, three, one at each side and one in the middle, or, if the number is large, one in the middle and one half-way between this and each side, would be advisable. You will have very little idea how uneven an apparently uniform soil may be until you make the trial.

OTHER FERTILIZERS TO BE TRIED.

9. It will be well, in the soil tests especially, to try other materials along with the experimental ones. Farm manures, ashes, and especially lime, are to be recommended.

SEE THAT ALL IS DONE RIGHTLY.

10. Attend to the work yourself. Don't trust it to the hired man unless you are sure he will do it better than you can.

MAKE ACCURATE OBSERVATIONS.

11. Watch the experiments closely. Note your observations. Make them both as accurate and complete as you can. Put down your notes when you make your observations. Do not trust them to future recollection.

REPORTS.

12. Make your reports as full and accurate as possible. Keep one copy for your own future use, and send the other in so that your results may be compared and published with others in good season. The benefit will not be yours alone, but you will share with others the good that will come from the combined work of all.

PLANS FOR CONTINUING THE EXPERIMENTS IN COMING YEARS.

To give the experiments the proper value they should be continued through a series of years with the same fertilizers on the same plots, and with either a rotation of crops or with the same crop year after year. It is hoped that a considerable number of the experiments may be thus repeated. For this the stakes bounding the plots must be kept in place.

THIS PROGRAMME IS NOT AS DIFFICULT AS IT SEEMS.

This may seem a pretty heavy programme for ordinary farmers. Of course the circumstances in which you work will require changes which your own good judgment will regulate.

Good things are not to be had without cost, and to those who have the spirit of the investigator — and there are many who have the spirit — the task is pleasant and not burdensome. Some of the most accurate, thorough, and valuable field experiments ever made in this country have been carried out by Connecticut farmers.

Besides the above directions, which were printed in pamphlet form, a separate sheet, of which the following is a copy, was sent to each experimenter.

TO BE TAKEN INTO THE FIELD. — CONDENSED DIRECTIONS.

1. Have your plans all made and everything ready before you start. Remember that worn-out soil for the soil tests, uniform soil for all, plots long and narrow and accurately measured and staked out, and right application of the fertilizers, are essential to the best success. Don't forget the tape or pole for measuring the plots, the scales for weighing, and pail for carrying the fertilizers, the stakes (four for each plot), and the earth for diluting the fertilizers if they are to be put in the hill or drill.

2. Select a fair average portion of the field to be tested and lay it out as accurately as you can. Leave an unmanured strip at least three feet wide, and preferably wider, between each two plots, to prevent the roots of the plants from feeding on their neighbor's fertilizers.

3. Designate each plot by a number, the unmanured by o, oo, ooo, and the manured by A, B, C, or 1, 2, 3, etc., corresponding to the number of the fertilizer. Put a strong stake firmly into the ground at each corner of each plot, and mark it with the number of the plot. If the plots are not staked and marked before the fertilizers are applied, you will risk making mistakes. When the fertilizer is applied to a plot, take the tag from the bag and fasten it to one of the stakes for a label.

4. Distribute each fertilizer evenly over its plot, and do not let it get outside. Lay your plans for doing this in advance, otherwise you may find the fertilizer all used up before you get to the end, or have some left over. Remember what was said about mixing well with the soil when put in the hill. If you do not you may kill some of the seed and injure the growth of the rest.

5. Be as systematic and accurate as you can, not only in starting the experiments, but in carrying them out, harvesting and measuring the produce and noting the results.

6. Arrangements like the following will be proper:

SOIL TESTS.

Plots one-tenth acre each.

Plot No.	Bag No.	Fertilizers.
o.		No manure.
A.	A.	Nitrogen.
B.	B.	Phosphoric Acid.
C.	C.	Potash.
D.	D.	Nitrogen and Phosphoric Acid.
E.	E.	Nitrogen and Potash.

Plot No.	Bag No.	Fertilizers.
F.	F.	Phosphoric Acid and Potash.
G.	G.	Nitrogen, Phosphoric Acid, and Potash.
H.	H.	Plaster.
OO.		No manure.

SPECIAL NITROGEN EXPERIMENTS.

Plots one-tenth or one-twentieth acre each.

0	No manure.	
1	Nitrate of Soda.	
2	Superphosphate.	
3	Muriate of Potash.	
4	Nitrate of Soda and Superphosphate.	
5	Nitrate of Soda and Muriate of Potash.	
6	Superphosphate and Muriate Potash.	"Mixed Minerals."
7	Mixed Minerals plus Nitrate of Soda.	$\frac{1}{3}$ Ration.
8	" " " Nitrate of Soda.	$\frac{2}{3}$ "
9	" " " Nitrate of Soda.	Full "
6*a*	Mixed Minerals. Duplicate of No. 6.	
10	Mixed Minerals plus Sulphate of Ammonia.	$\frac{1}{3}$ Ration.
11	" " " Sulphate of Ammonia.	$\frac{2}{3}$ "
12	" " " Sulphate of Ammonia.	Full "
6*b*	Mixed Minerals. Duplicate of No. 6.	
13	Mixed Minerals plus Dried Blood.	$\frac{1}{3}$ Ration.
14	" " " Dried Blood.	$\frac{2}{3}$ "
15	" " " Dried Blood.	Full "
6*c*	Mixed Minerals. Duplicate of No. 6.	
OO	No manure.	
	Farm manures or other fertilizers.	

SOURCES OF ERROR IN FIELD EXPERIMENTS WITH FERTILIZERS.

(The following statements were included with the explanations sent to the experimenters :)

There are two very common difficulties with field experiments: unevenness of the soil, and presence in the soil of plant-food which obscures the action of the plant-food in the fertilizers. Often duplicate plots differ as much from one another in yield as plots that receive different manures, and sometimes the unmanured plots produce more than the manured.

Few realize, until they have tried it, the difficulty in getting uniform soil for field experiments. A field or a portion of a field may look uniform and yet, when it is divided into plots, a crop grown, and the yield for each plot measured, the differences in the produce on the different plots may be considerable. Since these differences cannot be avoided entirely they should be made as small as possible.

The plant food in the soil, which interferes so seriously with many experiments for testing the action of fertilizers, may come from either natural accumulation or former manuring. That supplied by the natural processes by which the inert plant-food of the soil is made available to plants and by which the soil acquires plant-food from the air, belongs properly to the soil. The farmer ought to make the most he can of what his soil can thus supply to his crops. That from vegetable residues, roots, etc., is always present to greater or less extent, cannot well be removed, and does not seriously disturb an ordinary experiment, though on old grass land it accounts for a small part of the food the plants obtain. That from previous manuring of course interferes with the tests of the action of the experimental fertilizers, and its interference is in direct proportion to its amount. It ought, therefore, to be avoided.

To learn the practical effects of the fertilizers it is desirable to use worn-out land, that is to say, land which has been reduced by cropping. The methods of rotation practiced in Connecticut are generally such as to leave such worn-out lands in grass. Old meadows and pastures are therefore best for field experiments. Of course they will have some available plant-food, but it is just these worn-out soils which receive manure, and their deficiencies are the ones farmers oftenest need to know.

The most practical way to eliminate the errors caused by unevenness of soil is, doubtless, by duplicating the unmanured, or better, the manured plots. The plan sometimes followed in German experiments, of having an unmanured plot between each two manured, is excellent, but involves a large number of waste plots, and furthermore it would seem that the produce of duplicate manured plots would give fairer tests of the evenness or unevenness of soil than unmanured plots. In the Special Nitrogen Experiments here described, there is considerable duplication of manured plots. The essential part of the experiment is the testing of the effects of nitrogen in different amounts. The three mixtures which contain nitrogen in "one-third ration," "two-third ration," and "full ration," in addition to "mixed minerals" (superphosphate and "potash salt"), are applied on contiguous plots. On each side of this group is a plot with "mixed minerals" alone. Three such nitrogen groups are placed side by side with "mixed minerals" between. The "mixed minerals," which serve both as tests of the evenness of the soil and of what it will do without nitrogen, are thus used four times, and each quantity of nitrogen three times, in each experiment. In the experiments for soil tests the only duplication is with the unmanured plots. In those in which, along with the materials for soil tests, complete fertilizers in varying quantities are used, the plot of mixed minerals is repeated.*

The most satisfactory way to arrange field experiments is to grow crops without manure until the land is thoroughly worn down, and at the same time, by measuring the produce from plots, test the uniformity of the soil. This is being done by the Station on land of the Storrs School Farm at Mansfield.

THE EXPERIMENTS.

The experiments conducted during the season of 1888 may be divided into three classes:

I. Experiments for soil tests.

II. Experiments for testing the effects of different quantities of the same fertilizers.

III. Experiments for studying the effects of different quantities of nitrogen upon the corn crop.

SOIL TEST EXPERIMENTS.

The methods of conducting the experiments have been explained in detail in the foregoing pages. The fertilizing materials were supplied by the Station. Nitrogen, phosphoric acid, and potash were furnished in standard commercial forms, as nitrate of soda, sulphate of ammonia, dried blood, dissolved bone-black, and muriate of potash. These were put up in bags, the contents of one bag being sufficient for one plot; the bags for one experiment making a "set." The object of the "soil test" experiment is explained in the pamphlets referred to, in the following words:

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* As has been elsewhere explained (*e. g.*, Report of Conn. Board of Agriculture, 1880, pp. 345–6), a comparison of the yields on the different plots of experiments on these plans offer a peculiar but, apparently, very rigid test of the evenness of the plots. The further discussion of this and cognate matters is reserved for another place.

Chemical analysis is at best a tedious, costly, and, in the present condition of our knowledge, unsatisfactory means for determining the deficiencies of different soils and the economical ways of supplying them. Experiments in which plants are grown in small portions of soil in pots or boxes, have much in their favor, but for the farmer to test his own land, and as a means for the study of the most profitable ways of fertilizing a soil of a given kind, the method of applying different fertilizing materials to different plots of fields on which crops are grown, is found, by long experience, to be, on the whole, decidedly advantageous.

Experience in the field, explained by experiments in the laboratory, has clearly demonstrated that:

1. Soils vary greatly in their capabilities of supplying food to crops. Different ingredients are deficient in different soils.

2. Plants differ widely with respect to their capacities for gathering their food from soil and air. Hence the proper fertilizer in a given case depends upon the crop as well as upon the soil.

3. The chief use of fertilizers is to supply the plant-food which crops need and soils fail to furnish.

4. The only ingredients of plant-food which we need to consider in fertilizers are potash, lime, magnesia, phosphoric acid, sulphuric acid, and nitrogen. Of this list the magnesia is commonly, though not always, supplied in sufficient quantities in even "worn-out" soils. Sometimes its presence in fertilizers may be of considerable importance to crops. Sulphuric acid and lime are more often deficient, and hence one reason of the good effect so often observed from the application of lime and plaster. The remaining substances, the *phosphoric acid*, *potash*, and *nitrogen*, are the most important ingredients of our common commercial fertilizers, because of both their scarcity in the soil and their high cost. It is in supplying these that phosphates, bone manures, potash salts, guano, nitrate of soda, and most other commercial fertilizers are chiefly useful.

5. It is not good economy to pay high prices for materials which the soil may itself furnish, but it is good economy to supply the lacking ones in the cheapest way.

6. The only way to learn what materials are proper in a given case is by observation and experiment. The rational method for determining what ingredients of plant-food a soil fails to furnish in abundance, and how these lacking materials can be most

economically supplied, is to put the question to the soil with different fertilizing materials and get the reply in the crops produced.

7. The results of any given experiment are, in the main, applicable only to the particular case where it is made.

8. A single season's experimenting does not tell the whole story. To get complete results the trial must be carried through a series of years and crops.

Of course such experiments may, at best, fall short of their purpose. Other factors than the plant-food in fertilizers help to decide their value. Soils fail to furnish enough food to crops, not so much because they have not abundant stores as because the materials are not in available forms. The indirect action of fertilizers in improving the mechanical condition of the soil, increasing its absorptive power, and rendering its stores of plant food available, is often of much more consequence than their direct action in supplying plant-food.

The plan of the experiments for soil tests consists in applying on parallel plots of land, fertilizers containing nitrogen, phosphoric acid, and potash, singly, two by two, and all three together. The arrangement of the experiment, the kinds and quantities of the materials used and the valuable ingredients contained in them, are shown below:

EXPERIMENT FOR SOIL TEST.

Plan of Experimental Field.

Whole field, one acre, or more with farm manures or other fertilizers, and with unmanured strips between each two plots.

0. No Manure.
A. Nitrate of Soda.
B. Superphosphate.
C. Muriate of Potash.
D. Nitrate of Soda and Superphosphate.
E. Nitrate of Soda and Muriate of Potash.
F. Superphosphate and Muriate of Potash. "Mixed Minerals."
G. Nitrate of Soda, Superphosphate, and Muriate of Potash.
H. Sulphate of Lime (Plaster).
Farm Manure.
00. No Manure.

EXPERIMENTAL FERTILIZERS FOR SOIL TESTS. ACRE SET.

Number of Bag.	Fertilizing Materials.			Valuable Ingredients.		
	Kinds.	Amounts. Per Plot. lbs.	Amounts. Per Acre. lbs.	Kinds.	Amounts. Per Plot. lbs.	Amounts. Per Acre. lbs.
A.	Nitrate of Soda, . .	15	150	Nitrogen,	2.4	24
B.	Dissolved Bone-Black,	35	350	Phos. Acid,	5.6	56
C.	Muriate of Potash, .	15	150	Potash,	7.5	75
D.	Nitrate of Soda, . . Dissolved Bone-Black,	15 35	150 350	Nitrogen, Phos. Acid,	2.4 5.6	24 56
E.	Nitrate of Soda, . . Muriate of Potash, .	15 15	150 150	Nitrogen, Potash,	2.4 7.5	24 75
F.	Dissolved Bone-Black, Muriate of Potash, .	35 15	350 150	Phos. Acid, Potash,	5.6 7.5	56 75
G.	Nitrate of Soda, . . Dissolved Bone-Black, Muriate of Potash, .	15 35 15	150 350 150	Nitrogen, Phos. Acid, Potash,	2.4 5.6 7.5	24 56 75
H.	Plaster, ...	40	400			

Besides these it will be well to test the action of farm manures, lime, and other fertilizing materials.

DETAILS OF EXPERIMENTS.

Experiments coming under this class have been carried out, and in the following cases present results that appear to warrant publication : A. C. Blake, H. F. Wells, New Britain ; H. R. Stevens, Oxford ; H. F. Cox, Brooklyn ; Frank Day, Danielsonville ; N. G. Williams, Brooklyn ; T. A. Kirkham, Newington. On the following pages will be found tabulated forms giving condensed results of each experiment. In these are given the cost of fertilizers, the yields per plot in ears and stover as obtained in the field at the time of harvest, the yields per acre in bushels of dry shelled corn and in pounds of stover, and the gain or loss in bushels over an average of the nothing plots. In all cases the corn was found very green at the time of harvest, owing to the extremely wet autumn.

By actual trial, Mr. M. H. Dean of Falls Village found that it required 96.5 pounds of ears from the field at husking, to produce 56 pounds of thoroughly dried shelled corn. The experiment was made by drying 100 ounces behind a stove for twelve days. As corn dried in this way must have lost more moisture than it would have lost if dried in the crib, and for the sake of uniformity, it was thought best to calculate on the bases of 90 pounds of "good" and 100 pounds of "poor" for each bushel of dry shelled corn. These figures are used in the following tables for obtaining the yields per acre from the yields per plot as taken in the field. The cost of the fertilizers is based on the average selling price per ton during the spring of 1888, of the various ingredients used, to which has been added $1.20 per acre for applying, and thirty cents for mixing, where mixtures were used.

SOIL TEST WITH FERTILIZERS ON CORN.

BY ARTHUR C. BLAKE, NEW BRITAIN, CONN.

Number of Plot.	FERTILIZERS.			Yield per Plot (1-10 acre).			Yield per acre.			Gain or loss over Nothing Plots. Bushels per acre.
				Ears.			Shelled Corn.			
	KIND.	Weight per acre.	Cost per acre.	Pounds good.	Pounds poor.	Pounds Stover.	Bushels good.	Bushels poor.	Pounds Stover.	
0.	Nothing, ...	......	......	124	19	154	13.8	1.9	1540	......
A.	Nitrate of Soda, ...	150	$4.95	272	17	223	30.2	1.7	2230	11.1
B.	Dissolved bone-black, ...	350	5.65	212	8	212	23.6	.8	2120	3.6
C.	Muriate of Potash,.....	150	4.34	200	15	242	22.2	1.5	2415	2.9
D.	Nitrate of Soda, ... Dissolved bone-black,.......	150 350	9.70	273	8	263	30.3	.8	2630	10.3
E.	Nitrate of Soda, ... Muriate of Potash, ...	150 150	8.39	320	18	297	35.6	1.8	2965	16.6
F.	Dissolved bone-black, ... Muriate of Potash, ...	350 150	9.09	230	8	275	25.6	.8	2745	5.6
G.	Nitrate of Soda, ... Dissolved bone-black, ... Muriate of Potash, ...	150 350 150	12.84	332	18	281	36.9	1.8	2810	17.9
H.	Plaster, ...	400	2.50	189	23	207	20.9	2.3	2065	2.4
*00	Nothing, ...	......	......	218	18	213	24.2	1.8	2125	....

* Position in the field between F and G.

The field selected for this experiment is located in the red sandstone formation of the Connecticut valley, and has a gentle slope to the eastward. The soil is of medium compactness with a porous subsoil. It has had no stable manure since it came into possession of the present owner, in 1883, although commercial phosphates have been applied in small quantities. The field was twice sown to clover after oats, and each time the clover failed to give a good "catch." Clover was sown with oats in 1887, and on the south side of the field, including plots H, G, and 00, there was a scattering growth at the time the field was plowed for the experiment. This may account, in a measure, for the decided increase in yield on that part of the field.

The experiment field was visited August 4th, and the following notes made:

Plot 0. Pale yellowish color; rather light.

Plot A. Rich green, quite stocky; slighty better than B and C.

Plots B, C. Very similar; pale yellowish color; not as heavy as D and E.

Plots D, E. Good color; heavy; stocky growth.

Plot F. Lighter and less stocky in growth than D and E; pale, yellowish color.

Plot 00. Better than 0, but rather slender; pale.

Plot G. Uniform; stocky; medium heavy growth.

Plot H. Light growth; pale yellowish; uneven.

The results on the whole are not conclusive. The absence of nitrogen in the soil seemed to be most marked. Wherever this ingredient was omitted, there was a decided dropping off in the yield; and during growth the pale yellow tint of the foliage, together with the lighter growth of stalks, made its absence evident to the eye, in nearly every case.

SOIL TEST WITH FERTILIZERS ON CORN.

By H. F. Wells, New Britain, Conn.

Number of Plot.	Fertilizers.			Yield per Plot (1-10 acre).			Yield per acre.			Gain or loss over Nothing Plots. Bushels per acre.
				Ears.			Shelled Corn.			
	KIND.	Pounds per acre.	Cost per acre.	Pounds good.	Pounds poor.	Pounds Stover.	Bushels good.	Bushels poor.	Pounds Stover.	
0.	Nothing, ...	......	......	403	21	414	44.8	2.1	4140	......
A.	Nitrate of Soda, ...	150	$4.95	445	23	442	49.4	2.3	4420	.5
B.	Dissolved bone-black, ...	350	5.65	434	23	446	48.2	2.3	4460	—.7
C.	Muriate of Potash, ...	150	4.34	495	26	558	55.0	2.6	5580	6.4
D.	Nitrate of Soda, ... Dissolved bone-black, ...	150 350	9.70	428	23	473	47.6	2.3	4730	—1.3
E.	Nitrate of Soda, ... Muriate of Potash, ...	150 150	8.39	488	26	535	54.2	2.6	5350	5.6
F.	Dissolved bone-black, ... Muriate of Potash, ...	350 150	9.09	469	25	552	52.1	2.5	5520	3.4
G.	Nitrate of Soda, ... Dissolved bone-black, ... Muriate of Potash, ...	150 350 150	12.84	541	28	626	60.1	2.8	6260	11.7
H.	Plaster, ...	400	2.50	463	24	511	51.4	2.4	5110	2.6
*00	Nothing, ...	......	......	477	25	508	53.0	2.5	5080	....

* Position in the field between F and G.

The field selected by Mr. Wells has been in grass for many years, having been variously treated with commercial fertilizers prior to 1886, and like the preceding one is in the red sandstone formation. The soil is a heavy, compact loam, and apparently very uniform. It was covered with a heavy sod as the time of plowing, and, as is shown by the analysis of grass roots, stubble, and fall growth, published in another part of this report, must have been thus supplied with a liberal amount of nitrogen, phosphoric acid, and potash.

Potash gave a decided increase both in shelled corn and in stover, but not in paying quantities. Mr. Wells says a yield of forty to forty-five bushels of corn can be obtained from sod-land on his farm, without the use of manure of any kind.

SOIL TEST WITH FERTILIZERS. ON CORN.

By Howard R. Stevens,

On Farm of R. S. Hinman, P. O. Birmingham.

Number of Plot.	Fertilizers.			Yield per Plot.			Yield per Acre.		
	Kind.	Weight per Acre.	Cost per Acre.	Ears.		Pounds Stover.	Shelled Corn.		Pounds Stover.
				Pounds good.	Pounds poor.		Bushels good.	Bushels poor.	
0.	Nothing,..........................	......	...	222	31	261	24.7	3.1	2610
A.	Nitrate of Soda,..................	150	$4.95	231	37	220	25.7	3.7	2200
B.	Dissolved bone-black,.......	350	5.65	169	31	209	18.8	3.1	2090
C.	Muriate of Potash,.......	150	4.34	199	30	237	22.1	3.0	2370
D.	Nitrate of Soda,.................. Dissolved bone-black,.............	150 350	9.70	274	23	286	30.4	2.3	2860
E.	Nitrate of Soda,.................. Muriate of Potash,..............	150 150	8.39	306	15	316	34.0	1.5	3160
F.	Dissolved bone-black,............. Muriate of Potash,................	350 150	9.09	323	14	373	35.9	1.4	3730
G.	Nitrate of Soda,.................. Dissolved bone-black,......... .... Muriate of Potash,................	150 350 150	12.84	368	19	429	40.9	1.9	4290
H.	Plaster,............................	400	2.50	249	29	299	27.7	2.9	2990
I.	Complete Fertilizer,.......... Varied Forms,..................	600	16.00	383	18	475	42.6	1.8	4750

Mr. Hinman's farm is located in the town of Oxford, and extends from the valley of the Housatonic on to the high ground alongside. The field chosen for use in this experiment was upland sod that had been in grass for three years without the application of manure of any kind, and yielded about one-half ton of hay to the acre. The soil is light loam containing a medium amount of vegetable matter; subsoil loose, gravelly. The field is a level one, and the soil appeared very uniform, yet serious inequalities show themselves in the results of the experiment. The nothing plot, in this case, gave a larger yield than did several of the manured plots. The only way to account for this is through serious inequalities in the soil of different parts of the field. This difficulty may be partially overcome by continuing the work over a period of years.

SOIL TEST WITH FERTILIZERS. ON CORN.

By H. F. Cox, Brooklyn, Conn.

Number of Plot.	Fertilizers.			Yield per Plot. (1-10 acre.)			Yield per Acre.			Gain or loss over Nothing Plot. Bushels per Acre.
	Kind.	Weight per acre.	Cost per acre.	Ears.		Pounds Stover.	Shelled Corn.		Pounds Stover.	
				Pounds good.	Pounds poor.		Bushels good.	Bushels poor.		
*0.	Nothing,..........	......	......	148	30	246	16.4	3.0	2460	....
A.	Nitrate of Soda, ...	150	$4.95	152	35	205	16.9	3.5	2050	1.0
B.	Dissolved bone-black,.......	350	5.65	200	14	273	22.2	1.4	2730	4.2
C.	Muriate of Potash,..........	150	4.34	171	34	251	19.0	3.4	2510	3.0
D.	Nitrate of Soda,............. Dissolved bone-black,.......	150 350	9.70	304	14	309	33.8	1.4	3090	15.8
E.	Nitrate of Soda,........... . Muriate of Potash,..........	150 150	8.39	133	32	203	14.8	3.2	2030	-1.4
F.	Dissolved bone-black,....... Muriate of Potash,..........	350 150	9.09	378	14	314	42.0	1.4	3140	24.0
G.	Nitrate of Soda,............. Dissolved bone-black,..... . Muriate of Potash,..........	150 350 150	12.84	328	15	302	36.4	1.5	3020	18.0
H.	Plaster,.....................	400	2.50	114	36	204	12.7	3.6	2040	-3.1
I.	Complete Fertilizer....... Varied Forms,............	600	16.00	387	16	327	43.0	1.6	3270	25.2

* Position in the field between C. and D.

THE

Mr. Cox's field was worn-out grass land, which had not been manured for seven years. The soil was a heavy clay, rather wet. The field was selected partly because the soil was quite different from any of the others used in this class of experiments.

The season, however, proved decidedly unfavorable for the crop on this class of soils. No definite conclusion can be drawn as to the requirements of this soil from the past season's results.

SOIL TEST WITH FERTILIZERS. ON CORN.

By Frank Day, Danielsonville, Conn.

	Fertilizers.			Yield per Plot (1-10 acre).			Yield per acre.			Gain or loss over Nothing Plots. Bushels per acre.
Number of Plot.	Kind.	Weight per acre.	Cost per acre.	Ears.		Pounds Stover.	Shelled Corn.		Pounds Stover.	
				Pounds good.	Pounds poor.		Bushels good.	Bushels poor.		
0.	Nothing,	......	.....	237	30	177	26.3	3.0	1770	....
A.	Nitrate of Soda,	150	$4.95	234	54	275	26.0	5.4	2750	2.6
B.	Dissolved bone-black,	350	5.65	214	33	224	27.1	3.3	2240	1.6
C.	Muriate of Potash,	150	4.34	275	22	307	30.6	2.2	3070	4.0
D.	Nitrate of Soda, Dissolved bone-black,	150 350	9.70	360	34	336	40.0	3.4	3360	14.6
E.	Nitrate of Soda, Muriate of Potash,	150 150	8.39	320	24	421	35.6	2.4	4210	9.2
F.	Dissolved bone-black, Muriate of Potash,	350 150	9.09	344	8	369	38.2	.8	3690	10.2
G.	Nitrate of Soda, Dissolved bone-black, Muriate of Potash,	150 350 150	12.84	419	20	444	46.6	2.0	4440	19.8
H.	Plaster,	400	2.50	247	50	300	27.4	5.0	3000	3.6
I.	Complete Fertilizer, Varied forms,	600	16.00	397	12	470	44.1	1.2	4700	16.5
00.	Nothing,	.....	......	213	48	312	23.6	4.8	3120	....

The field selected for this experiment was situated on the bank of the Quinnebaug River, and was an old pasture that had not been plowed for many years. The soil was a light loam of medium compactness; subsoil very similar to surface, but with a small amount of vegetable matter. The land is what would be called typical corn land. The field was visited early in August, and on the whole the plots presented no marked differences. Mr. Day said: "The complete (G) has been ahead all the way through." Of the single element plots phosphoric acid was in advance, and seemed to be earing decidedly better than the others. It did not prove to be better, however, at the time of harvesting.

The experiment illustrates, in a decided manner, the advantages of commercial fertilizers over farm-yard manure, when the field is located at a considerable distance from the farm-buildings. This field was over a mile away, and Mr. Day estimated that the labor alone, of carting and applying a liberal quantity of manure, would have amounted to from ten to twelve dollars per acre. The fertilizers that brought the highest yield cost but $12.84, including expense of applying.

SOIL TEST WITH FERTILIZERS. ON CORN.

By N. G. Williams, Brooklyn, Conn.

Number of Plot.	Fertilizers.			Yield per Plot (1-10 acre).			Yield per acre.			Gain or loss over Nothing Plots. Bushels per acre.
	Kind.	Weight per acre.	Cost per acre.	Ears.		Pounds Stover.	Shelled Corn.		Pounds Stover.	
				Pounds good.	Pounds poor.		Bushels good.	Bushels poor.		
0.	Nothing,	......	......	144	82	418	16.0	8.2	4180	.. .
A.	Nitrate of Soda,	150	$4.95	321	48	539	35.7	4.8	5390	16.3
B.	Dissolved bone-black,	350	5.65	228	72	416	25.3	7.2	4160	8.3
C.	Muriate of Potash,	150	4.34	231	68	576	25.7	6.8	5760	8.3
D.	Nitrate of Soda, Dissolved bone-black,	150 350	9.70	325	52	654	36.1	5.2	6540	17.1
E.	Nitrate of Soda, Muriate of Potash,	150 150	8.39	314	68	734	34.9	6.8	7340	17.5
F.	Dissolved bone-black, Muriate of Potash,	350 150	9.09	237	67	625	26.3	6.7	6250	8.8
G.	Nitrate of Soda, Dissolved bone-black, Muriate of Potash,	150 350 150	12.84	232	62	678	25.8	6.2	6780	7.8
H.	Plaster,	400	2.50	150	76	429	16.7	7.6	4290	.1

Mr. Williams' field was on high ground. The soil was a light gravelly loam with a porous subsoil. The field had been in grass for several years, and at the time of plowing was considerably run down. The experiment was visited August 11th, and the following notes made:

Plot 0. Pale yellowish color; slender stalks.

Plot A. Dark green; stocky, earing well; best of single elements plots.

Plot B. Pale yellowish; stalks and ears light.

Plot C. Good color; earing fairly.

Plots D, E. Dark green; stocky; earing well.

Plot F. Lighter than D and E; stalks slender.

Plot G. Dark green; very stocky; earing well.

Plot H. Rather pale; stalks slender; ears small; no better than 0.

Mr. Williams said: "The nitrogen plot has been ahead since it got well started, although the phosphoric acid plot was better at first." Nitrogen alone seemed to give the most marked results of any in this class of experiments.

SOIL TEST WITH FERTILIZERS. ON POTATOES.

By T. A. Kirkham, Newington, Conn.

Number of Plot.	Fertilizers.			Yield per Plot (1-10 acre).			Yield per acre.			Gain or loss over Nothing Plots. Bushels per acre.
	Kind.	Weight per acre.	Cost per acre.	Pounds good.	Pounds poor.	Pounds total.	Bushels good.	Bushels poor.	Bushels total.	
0.	No Manure,..................	.....	.....	256	279	535	42.7	46.5	89.2	...
A.	Nitrate of Soda,.............	150	$4.95	348	242	590	58.0	40.3	93.3	8 9
B.	Dissolved bone-black,.....	350	5.65	398	233	631	66.3	38.8	105.1	15.7
C.	Muriate of Potash,.........	150	4.34	387	241	628	64.5	40.2	104.7	15 3
D.	Nitrate of Soda,.... .. .... Dissolved bone-black,......	150 350	9.70	438	230	668	73 0	38.3	111.3	21 9
E.	Nitrate of Soda.............. Muriate of Potash,..........	150 150	8.39	434	237	671	72.3	39.5	111.8	22.4
F.	Dissolved bone-black,....... Muriate of Potash,..........	350 150	9.09	506	224	730	84.3	37.3	121.6	32.2
G.	Nitrate of Soda,. .... Dissolved bone-black,....... Muriate of Potash,..........	150 350 150	12.84	522	185	707	87 0	30.8	117.8	28.4
00.	No manure,.................	......	......	323	214	537	53.8	35.7	89.5	....

The soil on Mr. Kirkham's farm is a medium loam, fine in texture, and apparently very uniform. The experiment, however, cannot be considered a success, as the whole field was attacked by a blight about the 10th of August, and the variety planted being a late one (White Star), the growth of the tubers was materially checked. The gradual movement of the disease over the field was apparent to the eye, at the time of harvest, by the increased yield on the side last attacked (west end of plots).

EXPERIMENTS WITH DIFFERENT QUANTITIES OF FERTILIZERS.

Many farmers apply large quantities of fertilizers to certain crops, because it is thought that liberal manuring is the most profitable. The best quantity depends upon a variety of conditions, and accurate tests are needed to show the range of profit. The Station instituted two experiments in this direction, with chemical fertilizers, on potatoes, only one of which is reported. The plan consisted in applying different quantities of the same fertilizers on three parallel plots. On account of the danger of the test being vitiated by irregularities in the soil, the experiment was duplicated, making two groups of three plots each. On each side of and between these groups of three, were plots with a mixture of dissolved bone-black and muriate of potash, called "mixed minerals." These serve to test the evenness of the soil and the effect on the yield where no nitrogen is applied. On each end of the field were unmanured plots, to show what the soil alone will produce.

It is found that potatoes generally respond to all three of the most important ingredients of commercial fertilizers, or in other words, that a complete fertilizer usually gives the best results on this crop. The crude materials used in these experiments to supply nitrogen, phosphoric acid, and potash, are from a variety of sources, on the hypothesis that the ingredients combined in a variety of forms are more efficient than where each comes from a single source. The mixture contained six per cent. of nitrogen, eight per cent. of phosphoric acid, and eleven per cent. of potash, and was applied at the rate of 600, 1200, and 1800 pounds per acre.

FIELD EXPERIMENT. ON POTATOES.

With Small and Large Quantities of Fertilizer.

BY H. S. MERWIN, DURHAM, CONN.

Number of Plot.	FERTILIZERS.			Yield per Plot. 1-10 Acre.			Yield per Acre.			Gain or Loss over Nothing Plots. Bushels per Acre.
	KIND.	Weight per acre.	Cost per acre.	Pounds good.	Pounds poor.	Pounds total.	Bushels good.	Bushels poor.	Bushels total.	
0.	No Manure, ...	.....	....	347	69	416	57.8	11 5	69.3	......
6.	Mixed Minerals,.....	500	$9.09	589	122	711	98.1	20.3	118.4	48.6
I.	Complete Manure,...	600	14 50 *1.50	596	143	739	99.3	23.8	123.1	53.3
II.	Complete Manure,...	1200	29.00 *1.75	612	140	752	102.0	23.3	125.3	55.5
III.	Complete Manure,...	1800	43 50 *2.00	672	185	857	112.0	30.8	142 8	73.0
6*a*	Mixed Minerals,.....	500	9.09	579	158	737	96.5	26.3	122.8	53.0
III*a*.	Complete Manure. ..	1800	43 50 *2 00	635	127	762	105.8	21.1	126.9	57.1
II*a*.	Complete Manure,...	1200	29.00 *1.75	609	113	722	101.5	18.8	120.3	50.5
I*a*.	Complete Manure,...	600	14.50 *1 50	533	143	676	88.8	23.8	112 6	42.8
6*b*.	Mixed Minerals,.....	500	9 09	489	135	624	81.5	22 5	104.0	34.2
00.	No Manure, ...	.....	....	320	102	422	53.3	17.0	70.3	......

* The upper figures represent the cost, and the lower the expense of mixing and applying.

Mr. Merwin's experiment was conducted on a portion of an old pasture, which, to the knowledge of the owner, had never before been cultivated. It was plowed in the fall of 1887, and consequently contained considerable quantities of decomposed vegetable matter. This may account for the large yield where no nitrogen is applied (mixed mineral plots).

The results of this experiment point decidedly toward a loss in the use of large quantities of fertilizing materials for potatoes, on land containing considerable quantities of decomposing vegetable matter.

SPECIAL NITROGEN EXPERIMENTS.

Farmers in Connecticut, as in all the older States of this country, are expending untold sums of money every year for crude chemicals and fertilizers rich in nitrogen. The commercial value of this nitrogen varies from eight to ten cents in hair, horn shavings, and coarse fish scraps, to sixteen or eighteen cents in nitrate of soda and sulphate of ammonia. While the commercial value of all forms of fertilizing materials is easily understood, being affected only by the supply and demand, their true agricultural value is modified by a great variety of conditions. The latter can only be measured by the returns in product and by the small quantity of the fertilizer left in the soil to benefit succeeding crops.

The amount of material left for the use of succeeding crops varies with the kind of fertilizers used and the soil to which it is applied. Serious losses often occur through leaching and chemical changes. In light, porous soils, much of the nitrogen passes beyond the reach of succeeding crops. There is little to be gained by applying such fertilizers as nitrate of soda in quantities much in excess of the requirements of the particular crop to be grown. These requirements vary with the natural fertility and physical condition of the soil, as well as with the kind of plant, and can only be determined by carefully conducted experiments.

The question of the nitrogen supply is one whose solution is most urgently demanded. As nitrogen is by far the most expensive of all the ingredients of plant food which the farmer needs to supply, the question becomes one of the utmost importance to every tiller of the soil. "No chemist or botanist can as yet tell the farmer just how the different plants of the farm stand related to nitrogen, for what ones, and in what quantities he must buy it, and what ones he can grow in rotation with other crops, and thus gather in from nature's stores, without money and without price, save the cost of tillage."

Carefully conducted field experiments, with the results interpreted by the light of the most advanced science, will go far toward a solution of many of these intricate questions. If, together with these, we have chemical and physical studies of the soil, analyses of the plants produced, and in addition pot and box experiments whose conditions may be definitely known and controlled, we may hope to gradually obtain the needed information.

The following, in connection with this subject, is taken from the pamphlet of "Directions" to which reference has already been made.

THE FEEDING CAPACITIES OF PLANTS.

These experiments bring us face to face with one of the most important problems with which agricultural chemistry has to deal, namely, to what may, perhaps, be most properly called the feeding capacities of different plants, their power of gathering their supplies of food from soil and air, and the effects of the artificial supply of different ingredients of plant food upon their growth.

A vast deal of experience in the laboratory and in the field bears concurrent testimony to the fact, though we are still deplorably in the dark as to how or why it is so, that different kinds of plants have different capacities for making use of the stores of food that soil and air contain. Of the ingredients of plant food in our soils, the most important, because the most costly, is nitrogen. Leguminous crops, like clover, do somehow or other gather a good supply of nitrogen where cereals, such as wheat, barley, rye, and oats, would half starve for lack of it, and this in the face of the fact that leguminous plants contain a great deal of nitrogen, and cereals relatively little. Hence a heavy nitrogenous manuring may pay well for wheat and be in large part lost on clover.

The tendency of late research is to indicate that some, at least, of the plants that make little response to nitrogenous manuring, obtain nitrogen from the air. Whatever the facts may be, they are of the greatest importance. Whatever can be done to bring new light upon the problem is worth attempting. One interesting fact brought out by late experimenting is that the corn plant seems possessed of a goodly share of this faculty of obtaining nitrogen from natural sources, though it is by no means safe to say, at present, that it draws much of its nitrogen directly from the atmosphere. But the power it appears to have of getting its own nitrogen, whether from soil alone, or from both soil and air, means more for the future of corn culture in New England than farmers have yet come to realize.

The question as to how much nitrogen plants can obtain from the atmosphere, is best studied by experiments on a small scale in the green-house and laboratory. The question of the profit or loss in using nitrogenous fertilizer, is a matter for field experiment. The specific problems to be studied in the experiments here referred to may be stated thus :

1st. How do the plants experimented with get on with the "mineral" fertilizers, such as are supplied by superphosphates and potash salts ?

2d. More especially, how do they respond to nitrogen when added, in different forms and amounts, to the mineral fertilizers ?

3d. And finally, what inferences may we draw as to the feeding capacities of the plants, their power to gather their food from soil and air, and the effects of different materials upon their growth, especial reference being made to the nitrogen supply ?

Several of the Annual Reports of the Connecticut Board of Agriculture have contained accounts of field experiments devised for the study of this especial question, and carried out by a number of farmers, agricultural colleges, and experiment stations, in Connecticut and elsewhere. The idea is to use the "mineral" fertilizers, superphosphate, and potash salt (which are here called "mixed minerals," and supply all of the ingredients of a "complete fertilizer" except nitrogen), as a basis of comparison, and to compare the produce from this mixture with that obtained when nitrogenous materials are added to it ; the increased yield in the latter cases being attributed to the nitrogen. The following quotations are from descriptions and directions prepared for the experiments :

"*The Object* of this experiment is to test the effects of nitrogenous fertilizers in different amounts and combinations upon the growth of the plant, and inferentially its capacity to gather its nitrogen from natural sources."

"*The Fertilizers.* — The ingredients and amounts are such as are used in ordinary practice : Phosphoric acid and Potash being supplied in about the proportions that occur in a corn crop of fifty or sixty bushels ; and Nitrogen in one-third, two-thirds, and full amount in same crop."

"*Forms of Nitrogen.*—The Nitrogen is supplied as Nitric Acid in Nitrate of Soda ; as Ammonia in Sulphate of Ammonia, and as Organic Nitrogen in Dried Blood."

"*Quantities of Nitrogen.*—The Nitrogen is applied at the rate of twenty-four pounds per acre in 'one-third ration' ; forty-eight pounds per acre in 'two-thirds ration'; and seventy-two pounds per acre in 'full ration.'"

"*Arrangement of Plots and Fertilizers.*— The ingredients are supplied as:

"Partial Fertilizers,	Group I. Nos. **1—3.** each by itself. Group II. Nos. **4—6.** Two by two.	Thus testing the effects of ingredients separately, and capacity of soil."
"Complete Fertilizers,	Group III. Nos. **7—9.** Nitrogen as nitric acid in nitrate of soda. Group IV. Nos. **10—12.** Nitrogen as ammonia in sulphate of ammonia. Group V. Nos. **13—15.** Nitrogen as organic nitrogen in dried blood.	Nitrogen in one-third, two-thirds, and full ration."

"The schedule provides for twenty plots, of which two are unmanured, and eighteen supplied with the experimental fertilizers. Of the latter, three, Nos. 6a, 6b, and 6c, are duplicates of the 'mixed minerals,' No. 6. This gives four plots of 'mixed minerals,' one on each side of each of the three groups, III, IV, and V, in which latter the effects of nitrogen are to be tested. This duplicating the 'mixed minerals' serves the three-fold purpose of testing the uniformity of the soil, replacing unmanured plots, and showing more accurately the actual effects of the nitrogen."

FERTILIZING MATERIALS FOR SPECIAL NITROGEN EXPERIMENT.

	FERTILIZERS.				
	KINDS.	Amounts per plot.		Amounts per acre.	Nitrogen per acre.
		Two-acre Set, for 1-10 acre plots.	One-acre Set, for 1-20 acre plots.		
		Pounds.	Pounds.	Pounds.	P'ds.
	Preliminary Group.				
1.	Nitrate of soda,	15.	7.5	150.	24.
2.	Superphosphate,	35.	17.5	350.	
3.	Muriate of potash,	15.	7.5	150.	
4.	Nitrate of soda,	15.	7.5	150.	24.
	Superphosphate,	35.	17.5	350.	
5.	Nitrate of soda,	15.	7.5	150.	24.
	Muriate of potash,	15.	7.5	150.	
6.	Superphosphate, Mixed minerals.	35.	17.5	350.	
	Muriate of potash,	15.	7.5	150.	
	Nitrate of Soda Group..				
7.	Mixed minerals, as No. 6,	50.	25.0	500.	
	Nitrate of soda, one-third ration,	15.	7.5	150.	24.
8.	Mixed minerals, as No. 6,	50.	25.0	500.	
	Nitrate of soda, two-thirds ration.	30.	15.0	300.	48.
9.	Mixed minerals, as No. 6.	50.	25.0	500.	
	Nitrate of soda, full ration,	45.	22.5	450.	72.
6*a*.	Mixed minerals, as No. 6,	50.	25.0	500.	
	Sulphate of Ammonia Group.				
10.	Mixed minerals, as No. 6,	50.	25.0	500.	
	Sulphate of ammonia, $\frac{1}{3}$ ration,	11.2	5.6	112.	24.
11.	Mixed minerals, as No. 6,	50.	25.0	500.	
	Sulphate of ammonia, $\frac{2}{3}$ ration,	22.4	11.2	224.	48.
12.	Mixed minerals, as No. 6,	50.	25.0	500.	
	Sulphate of ammonia, full ration,	33.6	16.8	336.	72.
6*b*.	Mixed minerals, as No. 6,	50.	25.0	500.	
	Dried Blood Group.				
13.	Mixed minerals, as No. 6,	50.	25.0	500.	
	Dried blood, one-third ration,	22.	11.0	220.	24.
14.	Mixed minerals, as No. 6,	50.	25.0	500.	
	Dried blood, two-thirds ration,	44.	22.0	440.	48.
15.	Mixed minerals, as No. 6,	50.	25.0	500.	
	Dried blood, full ration,	66.	33.0	660.	72.
6*c*.	Mixed minerals, as No. 6,	50.	25.0	500.	

Experiments of this class are reported from the following parties: The Station, Mansfield; E. H. Lathrop, Vernon Centre; M. H. Dean, Falls Village; W. I. Bartholomew, Putnam.

SPECIAL NITROGEN EXPERIMENT. ON CORN.

By the Station, Mansfield, Conn.

Number of Plots.	Fertilizers.			Yield per plot (1-20 acre).			Yield per acre.		
	Kind.	Weight per acre.	Cost per acre.	Ears.		Pounds Stover.	Shelled Corn.		Pounds Stover.
				Pounds good.	Pounds poor.		Bushels good.	Bushels poor.	
0.	No Manure,	.....	.....	27	59	134	6.0	11.8	2680
1.	Nitrate of Soda,	150	$4.95	26	62	121	5.8	12.4	2420
2.	Dissolved bone-black,	350	5.65	13	62	132	2.9	12.4	2640
3.	Muriate of Potash,	150	4.34	36	73	156	8.0	14.6	3120
4.	Nitrate of Soda, Dissolved bone-black,	150 350	9.70	27	76	129	6.0	15.2	2580
5.	Nitrate of Soda, Muriate of Potash,	150 150	8 39	39	77	150	8.7	15.4	3000
6.	Dissol. bone-black, Mixed Muriate of Potash, Min'als	350 150	9.09	75	59	158	16.7	11.8	3160
	Nitrate of Soda Group.								
7.	Mixed Minerals, as No. 6, Nitrate of Soda, ⅓ ration,	500 150	12.84	95	53	180	21.1	10.6	3600
8.	Mixed Minerals, as No. 6, Nitrate of Soda, ⅔ ration,	500 300	16.59	101	51	192	22.4	10.2	3840
9.	Mixed Minerals, as No. 6, Nitrate of Soda, full ration,	500 450	20.34	74	57	171	16.4	11.4	3420
6*a*.	Mixed Minerals, as No. 6,	500	9.09	53	66	160	11.8	13.2	3200
	Sulphate of Ammonia Group.								
10.	Mixed Minerals, as No. 6, Sulph. of Ammonia, ⅓ ration,	500 112	13 09	86	57	191	19.1	11.4	3820
11.	Mixed Minerals, as No. 6, Sulph. of Ammonia, ⅔ ration,	500 224	17.09	88	65	190	19.6	13.0	3800
12.	Mixed Minerals, as No. 6, Sulph. of Ammonia, full ration,	500 336	21.09	80	66	191	17.8	13.2	3820
6*b*.	Mixed Materials, as No. 6,	500	9.09	63	62	173	14.0	12.4	3460
	Dried Blood Group.								
13.	Mixed Minerals, as No. 6, Dried Blood, ⅓ ration,	500 220	13.16	71	62	175	15.8	12.4	3500
14.	Mixed Minerals, as No. 6, Dried Blood, ⅔ ration,	500 440	17.23	87	47	182	19.3	9.4	3640
15.	Mixed Materials, as No. 6, Dried Blood, full ration,	500 660	21.30	88	43	175	19.6	8.6	3500
6*c*.	Mixed Minerals, as No. 6,	500	9.09	51	58	150	11.3	11.6	3000
00.	No Manure,	.....	......	38	65	139	8.4	13.0	2780

This experiment was conducted on part of a worn-out grass field that had not received manure of any kind for seven years. The soil is a light loam, with medium amount of vegetable matter. The field was quite uniform, and gave promise of good results.

Heavy frosts of September 7th, however, checked the development on all of the plots; the corn became blanched, and as it did not appear to make further growth, was cut and stacked.

The potash (No. 3) appeared the best of the single element plots, throughout the entire season. The growth on the phosphoric acid plot was very uneven, and presented a pale, sickly appearance.

The corn was sufficiently advanced to show that the larger quantities of nitrogen failed to give any increase. One effect of fertilizers, owing to the shortness of the season, makes itself more noticeable in this experiment than otherwise would have been the case; the percentage of "good" corn is greatly increased where the larger quantities of fertilizers were employed. By good corn is here meant all ears sufficiently hard to be suitable for grinding, irrespective of size. The following are the averages from the mixed mineral and nitrogen plots:

	Percentage of "good" to total corn.
Mixed minerals,	49.4
Nitrate of Soda group,	62.4
Sulphate of Ammonia group,	59.8
Dried blood group,	61.8

The effect of fertilizers to push forward the crop, and thus shorten the season, is a point that should not be overlooked by farmers living in our variable New England climate.

Market-gardeners appreciate this valuable quality in fertilizers, and use large quantities of nitrate of soda to bring about a rapid and early development.

SPECIAL NITROGEN EXPERIMENT. ON CORN.

BY E. H. LATHROP, VERNON CENTER, CONN.

Number of Plot.	FERTILIZERS.			Yield per Plot. 1-10 acre.			Yield per acre.			Increase over Nothing Plots. Bushels per acre.
				Ears.			Shelled Corn.			
	KIND.	Weight per acre.	Cost per acre.	Pounds good.	Pounds poor.	Pounds Stover.	Bushels good.	Bushels poor.	Pounds Stover.	
0.	Nothing,....................	.. ..	.....	188	52	247	20.9	5.2	2470	......
	Nitrate of Soda Group.									
7.	Mixed Minerals, as No. 6,... Nitrate of Soda, ⅓ ration,..	500 150	12.84	289	42	385	32.1	4.2	3850	13.8
8.	Mixed Minerals, as No. 6,... Nitrate of Soda, ⅔ ration,..	500 300	16.59	273	46	335	30.3	4.6	3650	12.4
9.	Mixed Minerals, as No. 6,... Nitrate of Soda, full ration,	500 450	20.34	295	37	388	32.8	3.7	3880	14.0
[6.	Dissol. bone-black, } Mixed Muriate of Potash, } Min'als,	350 150	9.09	297	36	409	33.0	3.6	4090	14.1
	Sulphate of Ammonia Group.									
10.	Mixed Minerals, as No. 6, ... Sulp. of Ammonia, ⅓ ration,	500 112	13.09	262	48	327	29.1	4.8	3270	11.4
11.	Mixed Minerals, as No. 6,... Sulp. of Ammonia, ⅔ ration,	500 224	17.09	284	62	457	31.6	6.2	4570	15.3
12.	Mixed Minerals, as No. 6... Sulp. of Ammonia, full ration	500 336	21.09	304	43	460	33 0	4.3	4600	15.6
6*a*.	Mixed Minerals, as No. 6,...	500	9.09	270	48	399	30.8	4.8	3990	12.3
	Dried Blood Group.									
13.	Mixed Minerals, as No. 6,... Dried Blood, ⅓ ration,.......	500 220	13.16	234	56	367	26.0	5 6	3670	9.1
14.	Mixed Minerals, as No. 6,.. Dried Blood, ⅔ ration,.......	500 440	17.23	240	61	386	26.7	6.1	3860	10.3
15.	Mixed Minerals, as No. 6,... Dried Blood, full ration,.....	500 660	21.30	236	69	401	26.2	6.9	4010	10 6
	Nothing,....................	......	......	123	52	200	13.7	5.2	2000	......

The soil in this experiment is a light, porous loam, with little vegetable matter. Subsoil loose, sandy to gravelly. The field had been cropped with grass for a period of four years, without the use of manure ; the yield for the past year being very light. The land is well adapted to the growth of corn and rye, the latter having in previous years been grown very extensively. Fifty or sixty years ago rye was here alternated with fallow for a long period of years. Whether this constant cropping with one kind of plant brought about a one-sided exhaustion has not been determined. The field being limited in area, most of the soil-test portion of the experiment had to be omitted.

The small increase and consequent loss in money value by the use of the two-thirds and full rations of nitrogen is as marked in this experiment as any in its class.

The average total increase of the mixed minerals over the nothing plots is 13.2 bushels, while the average increase on the three full ration plots is but 13.3 bushels.

Too much weight should not be placed on the results of this experiment alone, as a part of the increase may perhaps be ascribed to the nitrogen supplied from the grass sod — furnished alike to mixed mineral and nitrogen plots.

SPECIAL NITROGEN EXPERIMENT. ON CORN.

By Myron H. Dean, Falls Village, Conn.

Number of Plots.	Fertilizers.			Yield per Plot 1-20 acre.			Yield per Acre.			Increase over Nothing Plots. Bushels per Acre.
	Kind.	Weight per acre.	Cost per acre.	Ears.		Pounds Stover.	Shelled Corn.		Pounds Stover.	
				Pounds good.	Pounds poor.		Bushels good.	Bushels poor.		
0.	No Manure,....	......	......	56	12	150	12.4	2 4	3000	.....
1.	Nitrate of Soda,...........	150	$4.95	116	14	194	25.8	2.8	3880	12.8
2.	Dissolved bone-black,.......	350	5.65	88	12	182	19.6	2.4	3640	6.2
3.	Muriate of Potash,..........	150	4.34	159	12	223	35.3	2.4	4460	21.9
4.	Nitrate of Soda,............ Dissolved bone-black,.......	150 350	9.70	98	22	185	21.8	4.4	3700	10.4
5.	Nitrate of Soda,............ Muriate of Potash,..........	150 150	8.39	176	18	232	39.1	3.6	4640	26.9
6.	Dissol. bone-black, } Mixed Muriate of Potash, } Min'rals	350 150	9.09	148	11	230	32.9	2.2	4600	19.3
	Nitrate of Soda Group.									
7.	Mixed Minerals, as No. 6,.... Nitrate of Soda, ⅓ ration....	500 150	12.84	214	16	280	47.6	3.2	5600	35.0
8.	Mixed Minerals, as No. 6,.... Nitrate of Soda, ⅔ ration,...	500 300	16.59	219	21	309	48.7	4.2	6180	37.1
9.	Mixed Minerals, as No. 6,.... Nitrate of Soda, full ration,..	500 450	20.34	206	23	298	45.8	4.6	5960	34.6
6*a*.	Mixed Minerals, as No. 6,....	500	9.09	131	10	201	29.1	2.0	4020	15.3
	Sulphate of Ammonia Group.									
10.	Mixed Minerals, as No. 6,.... Sul. of Ammonia, ⅓ ration,	500 112	13.09	177	12	238	39.3	2.4	4760	25 9
11.	Mixed Minerals, as No. 6,.. Sul. of Ammonia, ⅔ ration,	500 224	17.09	194	15	283	43.1	3.0	5660	30.3
12.	Mixed Minerals, as No. 6,.... Sul. of Ammonia, full ration,	500 336	21.09	186	21	340	41.3	4.2	6800	29.7
6*b*.	Mixed Minerals, as No. 6,....	500	9.09	142	8	210	31.6	1.6	4200	17.4
	Dried Blood Group.									
13.	Mixed Minerals, as No. 6,.... Dried Blood, ⅓ ration,......	500 220	13.16	176	9	260	39.1	1.8	5200	.25.1
14.	Mixed Minerals, as No. 6,.... Dried Blood, ⅔ ration,......	500 440	17.23	214	10	322	47.6	2.0	6400	33.8
15.	Mixed Minerals, as No. 6,.... Dried Blood, full ration,....	500 660	21.30	257	14	336	46.0	2.8	6720	33 0
6*c*.	Mixed Minerals, as No. 6,....	500	9.09	133	21	231	29.6	4.2	4620	18 0
00.	No Manure,................	......	.....	61	16	125	13.6	3.2	2500	......

A general description of the land used for this experiment is given in Mr. Dean's own words:

"The field selected for my experiment is a smooth and level one, free from stones, and lying on the banks of the Housatonic River. The soil is a light sandy loam, pretty thoroughly exhausted, having been cropped for many years without the application of fertilizers of any kind. It is a very suitable one for experimental work, for on such soil, whatever differences appear may be largely ascribed to the action of the fertilizers, and not to plant food already in the soil."

The field is an out-lying portion of the farm, and has been alternated with rye and pasturage for periods of three to four years each, for about twenty years, five to ten bushels of grain and a very light growth of straw being secured from an acre. A light rye stubble, together with a few weeds, was all the vegetable matter turned under when the field was prepared for the experiment. A marked result of this experiment is the beneficial effect, as shown by the heavy increase, from the use of potash, while phosphoric acid when used alone, was applied at an absolute loss. The value of the increase over the nothing plots, at sixty cents a bushel for shelled corn, is $8.80 per acre in the case of the potash (plot 3), while in the case of the phosphoric acid (plot 2) there is an actual loss of 62 cents. The response to nitrogenous fertilizers is greater here than in many experiments of this class, but the larger quantities show a decided falling off in the money value of the increase.

The gain or loss per acre over the nothing plots, from the use of mixed minerals, and the smaller and larger quantities of nitrogen, is shown by the following table:

Plots Used in Obtaining Averages.	Pounds Nitrogen.	Gain Dollars.	Loss Dollars.
Mixed Minerals (Plots 6 – 6*a* – 6*b* – 6*c*),....	00	1.41	....
⅓ Nitrogen ration (Plots 7 – 10 – 13),....	24	4.19	....
⅔ Nitrogen " (" 8 – 11 – 14),....	48	3.28	....
Full Nitrogen " (" 9 – 12 – 15),....	72	....	1.50

It will be seen at a glance that the profits from the nitrogen are in inverse ratio to the quantities used in excess of the one-third ration.

The value of this experiment is enhanced by favorable conditions, and the thoroughness and accuracy with which Mr. Dean has performed the work. The level and uniform condition of the land, the small amount of vegetable matter to be plowed in, and the badly "run out" condition of the soil made the field a very suitable one for the experiment.

The following is an abstract from a paper by Mr. Dean, read before the State Board of Agriculture, on the subject of his experiment:

"The fertilizer problem is one which has long occupied the attention of agriculturists. How to maintain the productiveness of his fields is the question which confronts the farmer as soon as his virgin soil begins to show signs of exhaustion. It is for the purpose of aiding the farmer in answering this question that these experiments are instituted.

"'Give me plenty of barnyard manure and you may have your phosphates,' is what we frequently hear men say. So say we, or would say, if the supplies of that article were unlimited. But, unfortunately, long before the wants of our soils are supplied, the precious material gives out, and we must content ourselves with small crops, or look about for a substitute.

The three kingdoms of nature have been searched again and again, if haply something might be found to stimulate our fields into increased productiveness. There was a time when the problem was thought to be solved. Chemistry showed that plants of the same kind were always composed of nearly the same elementary substances. They might be grown on different soils, but the composition remained the same. Thus the grains will always show a large percentage of phosphoric acid, and potatoes and root crops will show potash. The composition of our cultivated plants being determined, it was only necessary to get a chemist to analyze our soils to find if these substances were present there, and if not, to supply them, and the work was done. This was the theory, and a beautiful theory it was, but it failed to work in practice. The necessary amount of some of the substances is so small that when mixed with the great amount of soil, the chemist was unable to find it, or if found, it might be in a form not available for the use of plants.

What the chemist could not do, the living plant can. It sends its roots everywhere through the soil, and if the elements it needs are there, and in available forms, it will find them and thrive. If they are not there it will fail to grow. So we have made the plant our chemist, and in our experiments we have set it at work to find out for us the needs of our soils."

SPECIAL NITROGEN EXPERIMENT. ON CORN.

By W. I. Bartholomew, Putnam, Conn.

Number of Plots.	Fertilizers.			Yield per plot. (1-10 acre.)			Yield per acre.			Increase over Nothing Plots. Bushels per acre.
	Kind.	Weight per acre.	Cost per acre	Ears.		Pounds Stover.	Shelled Corn.		Pounds Stover.	
				Pounds good.	Pounds poor.		Bushels good.	Bushels poor.		
0.	No Manure,........	......	......	45	123	247	5.0	12.3	2470	......
1.	Nitrate of Soda,.............	150	$4.95	93	123	292	10.3	12.3	2920	1.7
2.	Superphosphate,............	350	5.65	178	124	396	19.8	12.4	3960	11.3
3.	Muriate of Potash,..........	150	4.34	125	146	276	13.9	14.6	2760	7.6
4.	Nitrate of Soda,............. Superphosphate,............	150 350	9.70	206	104	343	22.9	10.4	3430	12.4
5.	Nitrate of Soda,............. Muriate of Potash,........ .	150 150	8.39	123	138	366	13.7	13.8	3660	6.6
6.	Superphosphate, Mixed Muriate of Potash, Min'als.	350 150	9.09	287	103	451	31.9	10.3	4510	21.3
	Nitrate of Soda Group.									
7.	Mixed Minerals, as No. 6,... Nitrate of Soda, ⅓ ration,...	500 150	12.84	332	77	465	36.9	7.7	4650	23.7
8.	Mixed Minerals, as No. 6,... Nitrate of Soda, ⅔ ration,...	500 300	16.59	338	83	440	37.6	8.3	4400	25.0
9.	Mixed Minerals, as No. 6,... Nitrate of Soda, full ration,..	500 450	20.34	325	93	500	36.1	9.3	5000	24.5
6a.	Mixed Minerals, as No. 6,...	500	9.09	284	98	433	31.6	9.8	4330	20.5
	Sulphate of Ammonia Group.									
10.	Mixed Minerals, as No. 6,... Sulp. of Ammonia, ⅓ ration,	500 112	13.09	305	83	446	33.9	8.3	4460	21.3
11.	Mixed Minerals, as No. 6,... Sulp. of Ammonia, ⅔ ration,	500 224	17.09	291	93	467	32.3	9.3	4670	20.7
12.	Mixed Minerals, as No. 6,... Sulp. of Ammonia, full ration	500 336	21.09	278	110	469	30.9	11.0	4690	21.0
6b.	Mixed Minerals, as No. 6,....	500	9.09	304	91	491	33.8	9.1	4910	22.0
	Dried Blood Group.									
13.	Mixed Minerals, as No. 6,... Dried Blood, ⅓ ration,......	500 220	13.16	323	94	494	35.9	9.4	4940	24.4
14.	Mixed Minerals, as No. 6,... Dried Blood, ⅔ ration,......	500 440	17.23	329	103	550	36.6	10.3	5500	26.0
15.	Mixed Minerals, as No. 6,... Dried Blood, full ration,.....	500 650	21.30	316	92	522	35.1	9.2	5220	23.4
00.	No Manure,................	......	.....	116	116	305	12.9	11.6	3050	......

The field used for this experiment was a worn-out meadow, upland, sloping gently to the east; a clay, loam soil, with clayey subsoil. The soil is much the same as that upon which Mr. Bartholomew has conducted this class of experiments for a series of years, and the results of the past season simply confirm those of previous years. A ready response, with profitable returns from the use of phosphoric acid, shows itself in a very decided manner, as it has in all of his experiments during the past eleven years.

The gain or loss per acre over the nothing plots, from the use of mixed minerals, and the smaller and larger quantities of nitrogen, is shown by the following table:

Plots Used in Obtaining Averages.	Pounds Nitrogen.	Gain Dollars.	Loss Dollars.
Mixed Minerals (Plots 6 – 6*a* – 6*b*), ...	00	3.69	....
$\frac{1}{3}$ Nitrogen rations (Plots 7 – 10 – 13), ...	24	.83	....
$\frac{2}{3}$ Nitrogen rations (Plots 8 – 11 – 14), ...	48	....	2.63
Full Nitrogen rations (Plots 9 – 12 – 15), .	72	....	7.11

Increased value can be attached to Mr. Bartholomew's experiment, from the fact that similar ones have been made through quite a period of years on the same kind of soil. During the years 1878–81 he conducted a series of special nitrogen experiments, the results of which have been widely quoted by agricultural writers. In one experiment, the same plots and fertilizers were used for three successive years, the repetitions simply confirming the results of previous years.

These experiments have been compiled, and the results are published for comparison with the work of the Station during the past season.

A point made clear in these older experiments is, that no better results were obtained from the use of the larger quantities of nitrogen in the second and third year of the experiment than in the first. This tends to show that the nitrogen could not have all come from the refuse vegetable matter left over from the grass crop grown on the land previous to the starting of the experiment. It has been argued that much of the increase, when little or no nitrogen was used, could be accounted for by the plant's obtaining its nitrogen from this source, but these experiments fail to justify such a conclusion.

The next tabulation gives the results of Mr. Bartholomew's experiments, conducted under the direction of Professor Atwater, and published in the reports of the Connecticut State Board of Agriculture, 1878–81.

SPECIAL NITROGEN EXPERIMENTS.

CONDUCTED BY W. I. BARTHOLOMEW, PUTNAM, CONN.

Number of Plots.	FERTILIZERS.		Total Yield per acre.				
	KIND.	Pounds Nitrogen.	A. 1878.	B. 1879.	C. 1880.	D. 1881.	Average, A, B, C, D,
0.	No Manure,	....	17.7	7.7	22.2	7.3	13.7
1.	Nitrogen Mixture,	24	15.1	7.4	20.1	8.5	12.8
2.	Superphosphate, 300,	....	39.9	36.5	43.2	12.4	33.0
3.	Muriate of Potash,	....	19.1	7.7	24 7	10.0	15.4
4.	Nitrate of Soda, 150, Superphosphate, 300,	24	41.9	41.4	45.1	16.7	36.3
5.	Nitrate of Soda, 150, Muriate of Potash, 150,	24	21 1	7.1	24.0	5.5	14.4
6.	Superphosphate, 300 Mixed Muriate Potash, 150 Minerals.	....	43.1	42.0	52 8	25.2	40.8
7.	Mixed Minerals, as No. 6, Nitrate of Soda, 150,	24	51.7	45.7	50.0	28 8	44.1
8.	Mixed Minerals, as No. 6, Nitrate of Soda, 300,	48	47.3	46.8	54.0	22.6	42.7
9.	Mixed Minerals, as No. 6, Nitrate of Soda, 450,	72	47.3	42.2	56.2	18.8	41.1
10.	Mixed Minerals, as No. 6, Nitrogen Mixture, 150	24	50.0	44.0	47.2	31.0	43.1
11.	Mixed Minerals, as No. 6, Nitrogen Mixture, 300,	48	50.7	44.5	48.8	31.4	43.9
12.	Mixed Minerals, as No. 6, Nitrogen Mixture, 450,	72	56.4	39.1	50.9	31.1	44.4
13.	Mixed Minerals, as No. 6, Sulphate of Ammonia, 225,	48	58.1	40.2	51.2	24.4	43.5
14.	Mixed Minerals, as No. 6, Dried Blood, 450,	48	55.0	40.7	52.0	33.6	45.3
15.	Peruvian Guano (Standard), 550 Muriate of Potash, 150,	48	55.3	38.5	50.1	30.0	43.5
6*a*.	Mixed Minerals, as No. 6,	....	....	36.5	52.3	31.8	40.2
00.	No Manure,	....	....	8.5	37.8	12 4	10.5

The direct value of these experiments to the farmer cannot be more clearly shown, than by quoting from a paper read by Mr. Bartholomew before the Connecticut Board of Agriculture at its last annual meeting:

" To constantly accruing quantities of fertilizing materials in the soil, the farmer must look for the income from his investment in his farm. It is not enough for him to consider the field only a machine to manufacture a certain amount of supplied fertilizing material into a crop. He looks for at least a considerable portion of this material to be furnished from natural sources. While nearly all believe in this doctrine, it is quite unnatural to suppose that all kinds of soils furnish these materials in like proportion.

" Some fields, undoubtedly, yield more potash than others, some yield more phosphoric acid, while in others, perhaps, nitrogen is more easily obtained by the crop. These peculiarities of soil afford opportunity for the farmer's investigation. From experiments made at different times and places, it appears to be pretty well proven that the crops usually raised on the farm are not alike in their requirements of supplies from our hands. To furnish the same materials in all instances is wasteful extravagance, but to furnish each as needed is true economy. This principle is equally applicable in the use of farmyard manures. As these contain the elements of fertility in uncertain proportions, large quantities of some must remain unutilized, or lost to the crops. The nearer we come to furnishing the needful supplies without waste, the nearer we come to a correct use of fertilizers, whether we make use of barnyard manure or concentrated fertilizers. To attain this end every farmer should, to some extent, make his farm an experiment station, and in the growth of each season's crops find an agricultural school whose lessons should be of practical value.

" In the pursuance of this plan, it appeared to me that my corn received but little benefit from such fertilizers as nitrate of soda, sulphate of ammonia, and dried blood ; while to dissolved bones and other substances yielding phosphoric acid readily, a quick response was given. Muriate of potash alone did not pay, but in combination with phosphoric acid it gave better results than either alone. In a series of experiments conducted this year, this feature was quite as marked as in any previous instance.

"Permit me to allude to one other experiment made this year, which may be interesting. I had a field of corn which was planted, as is the usual custom in our section, with a good supply of stable manure — some thirty cart loads per acre. This amount we consider an extra manuring, the land previously being in good condition — the manure coming from a well-fed herd of cows. Most farmers would consider this supply sufficient for a good crop of corn. To this, on the greater part of the field, was supplied 200 pounds per acre of dissolved bone-black, but parts were left on which no bone-black was added. The yield of corn on the part which only had the manure was fifty-four bushels per acre. On the parts where both were applied it was sixty-four bushels per acre, giving me at the rate of ten bushels per acre for the addition of the superphosphate.*

"The results of both these are so similar to previous ones noticed during a period of some ten or fifteen years, that I cannot consider them as occasioned by accident. Do not understand by these remarks that I abstain from the use of manures containing nitrogen. I use them, but on other crops. Mixtures of these elements previously mentioned, similar to the ones containing the full ration nitrogen mixtures have proved so efficient on potatoes that I scarcely ever plant this crop without using them.

"To be successful we should not use the wrong fertilizers in the place of the right ones. They cost so much we cannot afford it. The old maxim, 'Know Thyself,' should be extended by the farmer to something like this: 'Know thyself, and understand thy farm.'"

---

* The cost of bone-black was $2.60 per acre.

PRACTICAL DEDUCTIONS.

It must be remembered that all experiments of this kind are subject to the vicissitudes of the weather, and that the crops are grown on poor soils for the purpose of avoiding all accumulated stores of fertility, so that in most cases the yields are necessarily light. The object of these field experiments is not to obtain large crops but to get comparative results with different kinds of fertilizing ingredients, under conditions otherwise as uniform as it is possible to secure. All of these conditions cannot be found, however, in any one field. Soils vary, not only as to the amounts of plant-food they contain, but as to slope, coarseness of grain, powers of absorbing heat and moisture, and retaining them when absorbed, and relative amounts of clay, sand, or humus in each, all of which influence their productions to a greater or less degree. The most carefully conducted experiment will be modified by a large number of uncontrollable conditions.

The value of an experiment depends in a marked degree on the season as well as on the soil. The past season has been a most unpropitious one for field work. Most of the reports from our experimenters contain remarks like the following: The lateness of the spring, cool nights during the summer, heavy rainfall during the latter part of the season, together with early frosts, made the season quite unfavorable for the crop.

In these experiments the largest yields, in most cases, were from the complete fertilizers. In many cases, however, one or two ingredients that seemed to meet the special requirements of that particular soil, gave much larger profits; for example, potash in Mr. Dean's case; phosphoric acid and potash (mixed minerals) with Mr. Bartholomew; and nitrate of soda (nitrogen) with Mr. Williams.

The conclusions from these and scores of similar experiments, both in this country and Europe, is that soils differ widely in their natural stores of fertility, and in the kind and quantity of the different ingredients they are able to supply to crops, that the soil should not be considered as a passive medium for holding a given amount of plant-food from the farmer's hand until needed by the crop, but as a great laboratory whose supplies of plant-food are constantly being worked over and converted by natural agencies into forms suitable for the use of the plant. As the primitive rocks in which soils have their origin vary widely in their composition, so must the soil coming from the breaking down of these rocks, vary quite as widely.

Our pioneer system of farming has been such as to draw upon the plant-food of soils differently. It appears to be true that phosphoric acid has been sold off the farm in bone, muscle, milk, and cheese, in greater quantities than the other essential constituents, and that it has not been returned in equal quantities in manures, fertilizers, etc.

The following tabulation, prepared from the results of eighty different experiments, conducted under the direction of Prof. Atwater during the years 1878–81, will be of value in this connection. The phosphoric acid (superphosphate) was called the regulating ingredient when the crop was largely benefited by it in every plot to which it was applied, and gave little or no response to the other materials. Where the crop paid less exclusive heed to the phosphoric acid, but was yet clearly benefited by it, it was called more or less efficient. Where the increase with phosphoric acid was less than four bushels per acre, it was counted as insufficient. The same rule was applied to the other materials.

Effect of Fertilizing Materials on Corn. Eighty Experiments.	Regulating Ingredient.	More or less Efficient.	Inefficient.
Superphosphate (Phos. acid),...........	29	34	17
Muriate of Potash (Potash),.............	12	24	44
Nitrate of Soda (Nitrogen),.............	4	30	46

From this table it will be seen that in twenty cases the crop responded uniformly to phosphoric acid, paying very little attention to the other ingredients, while in thirty-four cases, although not holding relatively so important a place, phosphoric acid was more or less useful. In seventeen cases this ingredient produced little or no effect. Where potash was used, the response was uniformly striking in twelve cases, more or less marked in twenty-four, while in forty-four cases very little effect came from its use. From nitrogen decidedly marked results were obtained in but four cases, in thirty it was quite useful, while in forty-six cases it did little or no good.

The results of these and other experiments indicate that phosphoric acid commonly, potash often, and nitrogen occasionally, are decidedly important ingredients of fertilizers for corn.

In the special nitrogen experiments the inefficiency, especially from a pecuniary point of view, of large quantities of nitrogen, is clearly shown. As soon as one-third nitrogen ration was exceeded, the profits became less, and the full rations were invariably used at a considerable loss.

The fact brought out by these experiments, and similar ones conducted in past years, is that corn can be grown with greater profit on mineral fertilizers alone, or with the addition of small quantities of nitrogen, than by the use of large amounts of this costly ingredient. The quantity of nitrogen it is advisable to use varies with different soils. Corn grown on soils that are naturally deficient in vegetable matter or humus, is generally benefited by nitrogenous fertilizers to a greater degree than where the soils contain abundance of this substance.

In the following table are given the results from the use of mixed minerals, and small and large quantities of nitrogen, in a large number of experiments conducted during a period of years from 1878 to 1881, and the average of those conducted by the Station during 1888. In preparing this table, the results from a large number of plots to which phosphoric acid and potash (mixed minerals) alone had been applied were averaged, for comparison with those furnished with the same mineral fertilizers but having in addition nitrogen equaling, approximately, one-third, two-thirds, and the full amounts contained in an acre of corn and stover yielding fifty to sixty bushels of shelled corn :

Yields per Acre.

Special Nitrogen Experiments.	Eighteen Experiments, 1878–'81, Bushels.	Four Experiments, 1888, Bushels.
Mixed Minerals alone,................	43.0	33.4
Same + 24 lbs. Nitrogen,............	48.4	38.2
Same + 48 lbs. Nitrogen,............	48.8	40.2
Same + 72 lbs. Nitrogen,............	49.6	39.2
75 *General Experiments.*		
Mixed Minerals alone,................	43.4	....
Same + 24 lbs. Nitrogen,............	47.8	....

It has been found that a crop of corn of fifty to sixty bushels, with the stalks, removes from the soil about seventy to seventy-five pounds of nitrogen. Thus, it will be seen, that where an amount of nitrogen equal to one-third, or even less of the total quantity represented in the crop, the corn is generally able to obtain from some source or other the remaining forty-eight or more pounds, and give about as good a crop as where the full amount of nitrogen represented in the crop is applied.

The important facts to be learned from all of these experiments are, that the corn plant has been able to develop and produce fair crops where mineral fertilizers alone were employed, even on our worn-out New England soils; that in some way corn does obtain large quantities of nitrogen from natural sources, either from soil, or air, or both, and that corn is unlike other cereals, as wheat and oats, and cannot be fertilized in the same way with profit.

CONCLUSIONS.

Taking into consideration these and similar experiments conducted in former years, the results show more clearly than ever that —

I. Soils vary widely in their natural stores of fertility, and hence in their capacities for supplying crops with food, and in their demands for fertilizers.

II. Farmers cannot afford to use commercial fertilizers indiscriminately, but that when properly used they are not only a valuable auxiliary to farm manures, but frequently produce better and larger crops when used exclusively, than where yard-manures are used alone.

III. The only way to determine the requirements of a soil for the production of any particular crop, is to put the question to the soil itself with different kinds and combinations of plant-food.

IV. Field experimenting must be considered an important branch of the work of Experiment Stations. If these experiments are carefully planned, faithfully carried out, and the results interpreted by the aid of the most advanced science, they will bring us nearer the solution of many important problems — problems too, such as the Eastern farmer has to contend with in the daily operations of the farm.

GRASSES AND FORAGE PLANTS GROWN DURING 1888.

In the Grass and Forage Garden on the farm of the Storrs School, a number of species and varieties of grasses, legumes, and other fodder plants have been sown, and sods have been set out. It is hoped that the number and kinds of plants may be greatly increased in the following years. The Station desires, with other things, to test not only the different grasses produced in Connecticut, including those found in old meadows and pastures in all parts of the State, but new grasses and forage plants as well.

Specimens of seeds have been furnished by the Department of Agriculture at Washington, by the Connecticut (New Haven) and Massachusetts Stations, and by private dealers.

The work in this direction was necessarily begun rather late in the spring, and some of the grasses have failed to mature. Another season this difficulty will be less felt. The more promising varieties will hereafter be selected and tested on a larger scale; a number of one-twentieth-acre plots having been laid out for this purpose.

The following is a list of the plants grown during the past season:

LIST OF PLANTS UNDER CULTIVATION IN THE GRASS AND FORAGE GARDEN.

Achillea millefolium,	Yarrow.
Agropyrum repens,	Couch-grass. Quack-grass.
Agrostis perennans,	Wood red-top.
Agrostis scabra,	Hair-grass. Thin grass.
Agrostis stolonifera,	Fiorin. Creeping bent-grass.
Agrostis vulgaris major,	Tall red-top.
Agrostis vulgaris minor,	Small red-top.
Aira flexuosa,	Hair-grass.
Alopecurus pratensis,	Meadow fox-tail grass.
Andropogon furcatus,	Blue-stemmed brome grass.
Andropogon scoparius,	Poverty grass.
Anthoxanthum odoratum,	Sweet vernal grass. Sweet-scented spring grass.
Apera spicata venti,	Awned bent-grass.
Arrhenatherum (Avena) elatior,	Tall meadow oat-grass.
Avena flavescens flexuosa,	Yellow oat-grass.
Bromus brixaeformis,	Briza-like chess.
Bromus tectorum,	Brome-grass.
Bromus secalinus,	Cheat. Chess.
Bromus unioloides (Ceratochloa australis),	Australian brome-grass.
Cynosurus cristatus,	Crested dog-grass.
Dactylis glomerata,	Orchard grass.
Deschampsia caespitosa,	Hair grass.
Dolichos Catiang, or D. sinensis, L.,	Cow-pea.
Elymus Virginicus,	Wild rye-grass.
Eragrostis poeoides,	
Festuca duriuscula,	Hard stemmed fescue-grass.
Festuca fluitans,	Water fescue.

Festuca heterophylla,	Various leaved fescue grass.
Festuca ovina,	Sheep's fescue-grass.
Festuca pratensis,	Meadow-fescue.
Festuca rubra,	Red fescue-grass.
Festuca tenella,	Small annual fescue-grass.
Festuca ovina tenuifolia,	Sheep's fescue-grass.
Hedysarum onobrychis,	Sainfoin.
Holcus lanatus,	Velvet-grass.
Lolium Italicum,	Italian rye-grass.
Lolium perenne,	Perennial rye-grass.
Lupinus albus,	White lupine.
Lupinus hirsutus,	Blue lupine.
Lupinus luteus,	Yellow lupine.
Medicago lupulina,	Black-seeded medick.
Medicago sativa,	Lucerne. Alfalfa.
Melilotus alba,	White melilotus. White sweet clover.
Melilotus cærulius,	Blue sweet clover. Bee clover.
Ornithopus sativus,	Serradella.
Panicum virgatum,	Tall panic-grass.
Panicum anceps,	Two-edged panic-grass.
Phalaris arundinaceæ,	Reed canary-grass.
Poa compressa,	Wire grass. English blue-grass.
Poa memoralis,	Woods spear-grass.
Poa serotina,	Fowl meadow-grass.
Poa trivialis,	Rough-stalked meadow-grass.
Trifolium hybridum,	Alsike clover.
Trifolium incarnatum,	French clover.
Trifolium pratense,	Common red clover.
Trifolium repens,	White clover.
Vicia sativa,	Spring vetch.
Vicia faba,	Horse bean.

EXPERIMENTS ON THE COW PEA.

In the spring of 1888, the Station received of F. P. Taylor of Athens, Tenn., a limited amount of the seed of the Southern cow pea. The plant has been grown at the Station and on a few farms in different parts of the State, with the following objects in view :

To determine its adaptability to our climate.

To study its value as a forage and ensilage crop.

To test its value for green manuring with a special view to its use in improving worn-out, light, or "plain land" soils.

Small quantities of the seed were sent to five farmers in the State, to test its value as a green fodder for feeding milch cows. Promising results were obtained in two cases, while in the other three early frost, or wet soils and excessive rains, prevented a good development. The season was such that a fair test could hardly be given. The results warrant a more extended trial during the coming season.

On the farm of the School about an acre of land was planted, and the crop harvested for ensilage. The seed was sown the third week in June, in drills three feet apart, one-half bushel of seed being used to the acre. The crop was harvested and placed in the silo Sept. 28 and 29. About one-half of the field was quite wet throughout a greater part of the season, and the growth was thus seriously checked, besides being damaged by early frosts. The balance of the field extended on to a hill-side, consisting of a loose, porous soil in a fair state of fertility. The yield on this portion of the field was a little less than eight tons (15,840 lbs.) of green fodder per acre, while a fair crop would be from ten to twelve tons. Arrangements are being made for testing the value of the ensilage for the production of milk, alongside of corn ensilage.

Under the direction of the Station an experiment has been instituted on the farm of S. T. Stockwell of West Simsbury, for studying the value of the plant as a green manure for rye. Three plots of one-tenth acre each were planted, the seed being sown broadcast at the rate of two quarts to the plot. The peas were killed by early frost when about ten inches high. The crop was plowed under, however, and the field sown to rye. The results must be awaited until the coming season.

This noted forage plant is to the Southern farmer what the clover is to the Northern. It has been extensively used for many years in the South as a forage plant and as a restorative crop on light and depleted soils. The average Southern farmer considers that his land is in better condition after the removal of a crop of the peas than it was before. Within the past ten years it has been grown with success as a forage crop in New Jersey and Massachusetts, and to some extent in Vermont, but not with marked success as far north as the last-named State.

The plant requires a warm soil, and good cultivation the first of the season. The seed should be sown about June 1st, or when the ground becomes thoroughly warmed. Should the plant be found adapted to our climate, it may become a valuable forage and ensilage crop, to use with corn. Fodder corn, or its ensilage, does not make a well-balanced ration; being deficient in nitrogenous or protein compounds. The composition of the cow pea is much the same as that of clover. It is rich in protein and can be fed to advantage with fodder-corn, thus making a better ration than the corn alone.

Below are given the average of six analyses of cow pea, grown as a forage plant, and the average of forty-eight analyses of fodder-corn.* As the water contents of the cow peas was not given in most cases, both have been estimated on the basis of dry matter or water-free substance.

Percentage Composition of Dry Matter.

	Av. 6 Anal. Cow Pea.	Av. 48 Anal. Fodder-corn.
Crude Protein,	15.36	8.57
" Fat,	2.72	2.16
" Fibre,	22.83	27.50
Non-nitrogenous extract matter,	49.20	55.84
Ash,	9.89	5.94

The thanks of the Station are due to Prof. Wm. H. Brewer of New Haven, who kindly prepared the following article at the solicitation of the vice-director. It will be read with much interest for its botanical value.

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* Connecticut Experiment Station Report, 1887.

THE COW PEA.

ITS ORIGIN AND BOTANICAL AFFINITIES.

By Prof. W. H. Brewer.

Many kinds of "cow pea" are grown in the United States. The number of varieties is said to be more than sixty, and they vary greatly in all their more noticeable characters. In all the varieties, the foliage, habits of growth, pods, seeds, and botanical affinities are those of beans rather than of peas, as these words are understood outside the Southern United States.

The varieties are very unlike in appearance and growth. In some the stems are short and nearly erect, the plant becoming in the hotter parts of the country biennial or even perennial; in other varieties the stems are long and twining like those of our Northern "pole beans." The pods vary greatly in appearance: some are short, others slender and nearly a foot long. The seeds vary even more: some are entirely white and in shape like small white beans, others are white with black or dark brown eyes, others are brown or dark brown or even almost black, some have the shape of true beans, others resemble lentiles or vetches in both size and shape, a few being nearly as round as peas. The seeds vary also in taste and probably in chemical composition. The varieties differ also in the shape of their leaves, in the length of the leaf-stalks, and the readiness with which the leaves fall on drying. The flowers vary in color and abundance. The kinds differ also in the soils they prefer, in the length of time required to mature, in their hardiness (although all are sensitive to frost), and so on through all their characters.

Because of these great differences, some botanists have described as several species what others consider only one. It is probable that most of our varieties belong to the species known to modern botanists as *Vigna Catiang*, Endl., a native of Northeastern Asia. The more important botanical synonyms are *V. Sinensis*, *Dolichos Catiang*, L., *D. Sinensis*, L., and *D. melanophthalmus*, D. C.

The genera *Dolichos* and *Vigna* both belong to the section of the Leguminosae to which the true beans belong. These genera have many species, natives of warm climates all around the world. Several species are cultivated, belonging to both genera, and the cultivated kinds have been carried to nearly all hot countries. As a consequence of this wide dispersion, it is now impossible to assign satisfactory limits to the species, and emphatically so of the cultivated ones, so whether all the varieties of "cow pea" are derived from only one original wild species or not, must remain a matter of opinion rather than demonstration among botanists, for the varieties have been cultivated so long that it cannot now be proved conclusively what the wild progenitor was. I strongly suspect that some few forms in the United States, known locally as "cow pea," belong to the species *Dolichos Lablab*, L. This species, also a native of India, and cultivated in various varieties, has been carried under various names to almost all hot countries, in some of which it has become naturalized and spread as a weed.

Both of these species (*V. Catiang* and *D. Lablab*) are extensively cultivated in Southeastern Asia, and Church, in his "Food Grains of India," gives many native names under which the varieties are known in the various districts, and the plants are noticed in all works that treat of the botany or agriculture of India.

The plant doubtless came to the United States from India. I am not aware of any account preserved of its introduction, but I suspect that it was introduced about the middle of the last century by the London "Society for the Promotion of Arts and Commerce." Under its auspices, and stimulated by its premiums, many other tropical plants were introduced and tried in the colonies. Cotton, various spices, poppy for opium, scanmony, cloves, alspice, etc., etc. And I think it probable that the "cow pea" thus came in. This, however, is mere conjecture.

As to why it is called "cow pea" I have no light whatever. One of the Hindoo or East Indian names is Cowlee, and enthusiastic philologists might think our name a corruption of that, but there is no other evidence than the sound that these names have any connection. The plant was written about as an agricultural plant in the South early in the present century, and then, as now, called "cow pea."

In 1873 I planted fourteen varieties, chiefly to learn their botanical, rather than their agricultural character. Some of them were small and nearly erect, others had twining vines ten or twelve feet long. All were beans rather than peas. None ripened; some which grew luxuriantly did not even blossom. Some produced pods six to eight inches long, which nearly ripened.

It is evident to me, that at best only a few of the many varieties can profitably be cultivated in New England; but it is also evident that many kinds must be tried, and for a series of years, before condemning the plant as unprofitable. I believe that varieties may be found that can be profitably grown, especially for milch cows. But the seed must come each year from some Southern locality. It has heretofore not been considered a profitable forage crop north of Delaware, except under very exceptional circumstances. But, by modern methods, we may and perhaps will make it pay for certain purposes in Connecticut. It flourishes well in sandy soils, and should have a new and fair trial.

PUBLICATIONS OF THE STATION.

The publications of the Station will be mailed to all citizens of Connecticut and to Granges, Farmers' Clubs, and other agricultural organizations, who ask for them, and so far as circumstances permit, to those who apply from other States. Requests for publications and business communications should be addressed to

STORRS SCHOOL AGRICULTURAL
EXPERIMENT STATION,
STORRS, CONN.

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EXPERIMENT STATION,
TOLLAND COUNTY. STORRS, CONN.

STATE OF CONNECTICUT.

SECOND ANNUAL REPORT

—OF THE—

STORRS SCHOOL

AGRICULTURAL EXPERIMENT STATION,

STORRS, CONN.

1889.

Printed by Order of the General Assembly.

MIDDLETOWN, CONN.
PELTON & KING, PRINTERS AND BOOKBINDERS.
1890.

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E. A. BAILEY,	*Assistant in Farm Experiments.*

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* In the absence of the Director of the Station, who is engaged in the duties of Director of the Office of Experiment Stations of the Department of Agriculture in Washington, the Chemist of the Station serves as Acting Director.

REPORT OF THE EXECUTIVE COMMITTEE.

To His Excellency Morgan G. Bulkeley, Governor of Connecticut:

In accordance with the Resolution of the General Assembly, concerning congressional appropriations to Agricultural Experiment Stations, approved May 18, 1887, and an Act of the General Assembly, approved March 6, 1889, entitled "An Act relating to the publication of Reports of the Storrs School Agricultural Experiment Station," we have the honor to present herewith the Second Annual Report of the Storrs School Agricultural Experiment Station.

RESOLUTION OF THE GENERAL ASSEMBLY CONCERNING APPROPRIATIONS TO AGRICULTURAL EXPERIMENT STATIONS.

Resolved by this Assembly:

SECTION 1. That this State accepts and assents to the provisions of the Act of Congress, approved March second, 1887, entitled "An Act to establish Agricultural Experiment Stations in connection with the colleges established in the several States, under the provisions of an act approved July second, 1862, and of the acts supplementary thereto."

SEC. 2. The farm attached to the Storrs Agricultural School may be used as an experimental farm for the purposes specified in the act first mentioned; and the trustees of that school and their successors in office are hereby appointed to receive and expend one-half of such moneys as may come to this State, under the provisions of said act first mentioned.

SEC. 3. The board of control of the Connecticut Agricultural Experiment Station, and its successors in office, is hereby appointed to receive and expend one-half of such moneys as may come to this State, under the provisions of said act first mentioned.

AN ACT RELATING TO THE PUBLICATION OF REPORTS OF THE STORRS SCHOOL AGRICULTURAL EXPERIMENT STATION.

Be it enacted by the Senate and House of Representatives in General Assembly convened:

SECTION 1. The Annual Report of the Storrs School Agricultural Experiment Station shall be printed, bound, and circulated as now provided by law for the Annual Report of the Connecticut Agricultural Experiment Station at New Haven.

SEC. 2. This act shall take effect from its passage.

ORGANIZATION OF THE STATION.

Of the $15,000 per annum received by Connecticut from the U. S. Treasury in accordance with the Act of Congress providing for Agricultural Experiment Stations, $7,500 are, by the above cited resolution of the General Assembly, entrusted to the Board of Trustees of the Storrs Agricultural School.

The farm and farm appliances and the labor of the students of the Storrs School are utilized by the Station. A building for the office of the Station was erected in 1888, and a barn for experiments in stock feeding is now being built on the grounds of the School. The experimental work at Mansfield, the Grass and Forage Garden there, and the field experiments throughout the State are under immediate charge of the Vice-Director. The chemical and other more purely scientific investigations are carried out at Wesleyan University, Middletown, which gives free use of needed room and appliances in its chemical and biological laboratories for the purpose. By this means much expense is saved to the Station, and it is enabled to prosecute inquiries larger in amount and more useful in character than would otherwise be possible with its limited revenue.

The spirit of the Board of Trustees of the School in the management of the Station is expressed in the following from the report of the Committee on Organization of the Station, which was adopted by the Board at its meeting March 27, 1888:

> "It shall be a recognized function of the Station to communicate freely with the farmers of the State, both in regard to results attained and work to be undertaken. It will labor for the establishment and maintenance of very intimate and mutually helpful relations between itself and them.
>
> "It proposes to be guided by their intelligent desires in the line of work to be undertaken, and hopes for their active coöperation in carrying it forward.
>
> "To this end it invites the assistance of all agricultural societies, granges, farmers' clubs, and all associations which may help it or be helped by it, in the work of promoting the welfare of Connecticut agriculture."

The Executive Committee have endeavored to keep always in view the declarations recommended by the Committee on Organization, and adopted by the Trustees, in deciding the line and scope of work to be undertaken. In this they have the hearty coöperation of the officers and employes of the Station, to whose ability, zeal and industry they are happy to bear testimony.

At the expiration of his time of service (July 1, 1889,) as member of the Board of Trustees of the School, Mr. J. P. Barstow resigned the office of Treasurer of the Station, and the Board appointed Mr. Henry C. Miles in his stead.

The Committee refer to the accompanying report of the Treasurer for details of expenditure and to that of the Director and his assistants for the history of the work accomplished.

The accounts* of the year which are summarized in the report of the Treasurer were duly audited by the Auditors of the State Public Accounts.

Respectfully submitted,

T. S. GOLD,
J. M. HUBBARD,
B. F. KOONS,
Executive Committee.

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* An account of the organization and work of the Station was presented, with the report of the Treasurer, which follows, to the Governor of the State for record and transmittal to the Secretary of Agriculture and to the Secretary of the Treasury of the United States, in accordance with the Act of Congress approved March 2, 1887.

REPORT OF THE TREASURER FOR THE FISCAL YEAR ENDING JUNE 30, 1889.

The following summary of receipts and expenditures is made out in accordance with the form recommended by the Association of American Agricultural Colleges and Experiment Stations, and approved by the United States Treasury Department:

TABULAR STATEMENT OF RECEIPTS AND EXPENDITURES.

RECEIPTS.

U. S. Treasury,	$7,500 00
Sale of apparatus,	135 10
Discount on bills,	10 90
Corn, stover, etc., sold to Storrs Agricultural School,	64 10
	$7,710 10

EXPENDITURES.

Salaries,	$4,068 96
Bacteriological investigations,	500 00
Building,	40 91
Steam and gas fittings,	269 00
Traveling expenses,	141 73
Executive Committee,	115 17
Stationery,	140 74

Postage and Telegraph,		$17 31
Telephone,		45 00
Printing bulletins and report,		231 50
Library,		97 05
Farm and field experiments, labor,	$263 42	
" " " other than labor,	533 27	
		796 69
Office furniture,		17 10
Agricultural implements,		40 95
Team,		127 37
Apparatus, more or less permanent,	268 68	
" for immediate consumption,	244 72	
		513 40
Chemicals,		141 76
Coal, gas and oil,		255 96
Hardware,		18 29
Lumber,		5 70
Freight, cartage and express,		63 31
Pot and box experiments,		16 47
Incidentals,		43 88
Balance in treasury,		1 85
		$7,710 10

J. P. BARSTOW,

Treasurer.

Report of the Director.

During the year the following lines of work have been pursued by the Station:—

1. The coöperative field experiments with fertilizers begun last year have been continued by the Station and by farmers on their own farms in different parts of the State. These experiments are for the purpose of testing the different needs of soils and crops and the most economical ways of supplying them. In plan and scope they are essentially the same as those since recommended to the Stations by a convention of Station Directors held in Washington in March, 1889, and published by the Office of Experiment Stations in Circular No. 7, March, 1889.

2. In connection with the field experiments chemical analyses of the products have been made to study the effect of the different fertilizers upon the composition of the plant. Some one hundred and sixty-five proximate analyses of corn, grain and stover have been completed.

3. Not far from forty analyses of food and fodder materials have been made besides those of corn already mentioned.

4. The experiments on the effects of tillage upon soil moisture have been continued, with results differing but little from those of 1888.

5. Grass and forage plants have been grown by the Station in its Grass and Forage Garden and elsewhere, especial attention having been given to the cultivation of leguminous plants not ordinarily grown in the State.

6. Experiments upon the sources of the nitrogen of plants with especial reference to the acquisition of atmospheric nitrogen have been a feature of the Station work during the past year. Over two hundred experiments have been made with peas, beans, cow peas, alfalfa, corn and oats. Some of the results were published in the October Bulletin of the Station. These investigations are in the line of previous ones at Wesleyan University, which proved that some plants (peas) acquire nitrogen in relatively large amounts from the atmosphere, and later work by European investigators which has verified the results obtained here and

shown the connection of microbes with the process. Investigations are being planned which, it is hoped, may throw more light upon the ways by which the atmospheric nitrogen is obtained by the plants.

7. The investigation of the value of stubble and roots of plants as manure has been continued, especial attention having been given to the legumes.

8. Meteorological observations have been made at the Station throughout the year, and the rainfall has been observed in connection with the field experiments in different parts of the State during the growing season.

9. The experiments upon bacteria in milk and its products, commenced in 1888 under the direction of H. W. Conn, Ph. D., Professor of Biology at Wesleyan University, have been continued with interesting results. A brief account of this investigation was given in the July Bulletin of the Station.

10. A barn is being built for the Station, and plans are being made for feeding experiments with a special bearing upon milk production and dairying.

11. Investigations have been made with the calorimeter, the object being the determination of the heats of combustion of the constituents of animal and vegetable products used for food. The potential energy thus determined is taken as a measure of the fuel-values of the substances in nutrition.

12. During the year the Station has published its Annual Report and three Bulletins, aggregating 150 pages.

The Director has spent a large portion of the year in Washington in charge of the Office of Experiment Stations of the U. S. Department of Agriculture, and has been able to exercise only a general supervision of the work of the Station. In his absence the Chemist of the Station, Chas. D. Woods, serves as Acting Director. The Director wishes to express his appreciation of the care and thoroughness with which details have been carried out and reported by the gentlemen to whom they have been entrusted.

W. O. ATWATER,
Director.

THE ACQUISITION OF ATMOSPHERIC NITROGEN BY PLANTS.

BY

W. O. ATWATER and C. D. WOODS.

Until lately it has been the prevalent though not universal opinion of chemists and vegetable physiologists that the free nitrogen of the air is not assimilated by plants and that, as the proportions of combined nitrogen in the atmosphere are so minute that the amounts which ordinary plants could absorb during their growth must be unimportant, nearly all of the nitrogen of plants is furnished to them by the soil, either from previously accumulated stores or from fertilizing materials applied to it. In 1881 the present Director of this Station instituted a series of experiments, which were repeated in 1882, and brought positive evidence of the acquisition of large quantities of nitrogen from the air by peas during their period of growth. The investigation was unavoidably interrupted until 1885, when four other series revealed large losses of nitrogen during germination and early growth. In the account* of these later investigations it was urged that this loss of nitrogen was probably caused by microbes; that it helped to explain why previous experimenters had failed to find proof of acquisition of atmospheric nitrogen by plants, especially legumes, but that the negative results obtained by the latter were also due to the exclusion of the action of electricity or microbes, by which the assimilation of atmospheric nitrogen might be aided.

The circumstances which caused the cessation of the investigation from 1883 to 1885 were alike operative from the latter time until 1888, when the organization of the chemical work of the Station in the chemical laboratory of Wesleyan University, where the previous investigations had been made, rendered their continuation possible. Meanwhile the very important investigations of Hellriegel† and others had confirmed those of the first and second series referred to, and, while bringing additional evidence of the acquisition of atmospheric nitrogen, had also indicated the very strong probability that micro-organisms are active agents in the assimilation of nitrogen.

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* The results of the experiments of the first series were reported briefly at the meeting of the American Association for the Advancement of Science in 1881, those of the first and second series together were reported at the meetings of the British and the American Association for the Advancement of Science in 1884, and in detail in the *American Chemical Journal*, Vol 6, p. 365, (February, 1885). Those of series three to six were reported in the same journal, Vol. 8, pp. 327 and 398.

† Hellriegel and Wilfarth, Unters. u. d. Stickstoffnahrung der Gramineen und Leguminosen, Beilageheft z. d. Zeithsch. des Vereins f. d. Rübenzucker-Industrie d. D. R., Nov., 1888.

The experiments herein described are a continuation of the previous ones in this place. The methods are also similar, save that the introduction of soil infusions and observations on root tubercles were suggested by the experience of Hellriegel.

The specific question for study in the first series of experiments here was:—

(1) May plants, peas, grown under normal conditions acquire any considerable amount of nitrogen, free or combined, from the air?

The second series was planned to verify the strongly affirmative results of the first and to include the collateral inquiry:—

(2) How is the acquisition of nitrogen from the air affected by abnormal conditions of growth?

In the present investigation the study of the first question is continued with peas and other plants, legumes and cereals, and the two further questions have been included:—

(3) What effect has the addition of soil infusions upon the formation of root tubercles under the conditions of the experiments?

(4) Is there a definite relation between the quantity or number of root tubercles and the quantity of atmospheric nitrogen obtained by the plant?

PREVIOUS EXPERIMENTS IN MIDDLETOWN.

Before entering upon the details of the work to be reported herewith, a recapitulation of the experiments of the first two series above referred to may be appropriate. The plan of the experiments was similar to that of the ones to be reported beyond. The plants were grown in purified sand, supplied with solutions of appropriate salts including nitrogen and nitrates, and kept in open air, but protected from rain and dew. The first series included five, and the second twelve experiments. The figures of numbers five to twelve of the second series given in the table herewith will, with the explanation quoted, suffice to illustrate the results obtained.

The "concentrated" solutions contained from 2.5 to 6, and the "dilute" from 0.3 to 1.6 parts of water-free salts in 1000. A concentration of 1 per 1000 has elsewhere been found favorable, and one of over 2 per 1000 unfavorable to normal assimilation.*

The well-fed plants had quantities of mineral food estimated to be sufficient for their nourishment, the scantily fed ones, one-half as much. The "larger nitrogen ration" was estimated to supply an amount of nitrogen rather small in proportion to the mineral food, and the "smaller nitrogen ration" less than one-half as much as the larger. The gain or loss of nitrogen is computed by adding to the amount of nitrogen in the plants the amount left in the nutritive solution at the end of the experiment, and subtracting from their sum the sum of the amounts in the seed and in the nutritive solution at the start. The figures for "apparent gain or loss" represents, therefore, the quantities acquired from the air less whatever may have been liberated from solution or seed or plants during growth.

Statistics of Experiments on the Assimilation of Atmospheric Nitrogen by Peas.

Conditions of Experiments.			No. of Experiment.	Nitrogen Supplied.			Nitrogen found at End of Experiment.			Apparent Gain + or Loss — of Nit'g'n
				In Seeds.	In Nutritive Sol'n.	Total.	In Plants.	In Residual Solu'n	Total.	
				Mg	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.
Larger Nitrogen Ration,	Concentrated Solution,	Scantily fed,	3	70.3	136.9	207.2	197.5	12.7	210.2	+ 3.0
		Well fed,	6	34.8	136.9	171.7	149.6	1.2	150.8	— 20.9
	Dilute Solution,	Scantily fed,	12	68.8	136.9	205.7	260.2	45.7	305.9	+100.2
		Well fed,	10	34.6	136.9	171.5	277.8	35.7	313.5	+142.0
Smaller Nitrogen Ration,	Concentrated Solution,	Scantily fed,	7	71.5	59.4	130.9	158.1	0.0	158.1	+ 27.2
		Well fed,	5	34.2	59.4	93.6	156.1	0.0	156.1	+ 62.5
	Dilute Solution,	Scantily fed,	11	72.5	59.4	131.9	210.9	2.7	213.6	+ 81.7
		Well fed,	9	35.3	59.4	94.7	186.5	1.4	187.9	+ 93.2

The following statements are from the summary of the conclusions, which embodies also those of the four series of experiments on the liberation of nitrogen during germination and the early growth of peas above referred to as undertaken in connection with this investigation:

1. "The experiments showed in some cases a large acquisition of nitrogen from the air, the gain amounting in some instances to half or more than half of the whole nitrogen in the plants. In other cases there was, apparently, a very small gain or a loss of nitrogen. There seems to be excellent ground for assuming that

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* We have found plants to grow well in more concentrated solutions, (see also Hellriegel, Naturwiss., Grundlagen des Ackerbaus,) but in these experiments, at any rate, there was less apparent gain of nitrogen with the concentrated than with the dilute solutions.

the cases in which either only a small gain or a loss of nitrogen was observed (in all of which the conditions of growth were abnormal) are to be explained by the escape of nitrogen from either the nitrates of the nutritive solution or from the seeds during germination, or from the growing plants. The proof of the acquisition of atmospheric nitrogen which is furnished by the cases in which the conditions of growth were normal, in each of which the amount acquired was large, is thus rendered the more emphatic. The faculty of obtaining nitrogen from the air appears to be especially characteristic of the legumes. By what species of legumes or other families of plants it is possessed, it is as yet impossible to say."

2. "The liberation of nitrogen appears to be due, in some cases if not in all, to ferments. To explain why it should take place in one case and not in another, is as difficult as to account for the fact that zymotic diseases attack one animal and not another, or that the plants of certain fields are affected by fungi, while others escape. It is, however, noticeable that in nearly all the experiments in which no gain of nitrogen has been observed the plants have been ill fed, or the nutritive solutions have been very concentrated, or other conditions have been abnormal; while, so far as the details at hand show, the largest gains have been found in the cases where the conditions of growth were most favorable."

3. "How the nitrogen was obtained in the experiments in which its acquisition is proven is still a matter of doubt. It must have been taken as either free or as combined nitrogen, and either directly through the foliage or indirectly through the soil and nutritive solutions and the roots of the plants."

4. "It would be going too far to positively assume that in the experiments which have given the strongest evidence against the fixation of free nitrogen by plants—namely, those of Boussingault and of Lawes, Gilbert and Pugh, in which the plants were raised under glass, in confined air or in air washed free from nitrogen compounds—the negative results are due to escape of nitrogen in the manner above suggested, though such liberation cannot be regarded as impossible. But it is at least conceivable that the measures adopted to exclude nitrogen compounds—keeping the plants under glass and passing the air through acid and alkali solutions before entering—may have excluded the action of electricity or of microbes, by which the fixation of free nitrogen may perhaps be effected. The plants

were also, for the most part, very poorly fed. That this may be the cause of deficient assimilation of nitrogen is indicated by the experiments with peas above referred to. At any rate, until we know more about the relations of electricity and of micro-organisms to the fixation of nitrogen, we can hardly be warranted in assuming that these experiments prove that plants grown under normal conditions do not assimilate the free nitrogen of the air."

5. "To what extent the attested acquisition of atmospheric nitrogen is a function of the plant alone; in how far it may be dependent upon the action of electricity, microbes, or other agency induced by the plant; by what species of plants and under what conditions it is accomplished, are of course matters for further study. The experiments of Berthelot imply that organic matter, through the agency of electricity, and soils containing clay, through the agency of living organisms, may fix the free nitrogen of the air. It may hence be inferred that in some of the experiments in which acquisition has been observed, the nitrogen may have been first taken from the air by the medium in which the roots grew and communicated through the latter to the plants. But in my experiments this medium consisted of ignited sea-sand and an aqueous solution of salts. I am aware of no observed facts to imply that these, separately or together, are able to fix free nitrogen by aid of electricity, micro-organisms, or any other means. In the present state of our knowledge, therefore, the balance of probability seems to decidedly favor the assumption that the plants themselves must be factors in the acquisition of atmospheric nitrogen."

6. "Messrs. Lawes, Gilbert and Warrington have shown the great probability that the legumes, which appear to possess in high degree the power of obtaining nitrogen from natural sources, induce the action of nitrifying ferments by which the inert nitrogen of the soil is made available. It is equally conceivable that the same plants and others may favor the action of nitrogen-fixing micro-organisms."

PLAN OF THE EXPERIMENTS HERE REPORTED.

The plants in the experiments here described were all grown in purified sea-sand. A number of trials were made by water culture, and two (with corn) in ordinary garden soil. A difficulty with the last is that no method which we have as yet been able to find for the determination of nitrogen will admit of its estimation with the desired accuracy in the large amount of soil needed for satisfactory development of the roots.

Effort has been made to grow the plants under conditions as nearly normal as is consistent with a rigid control over the supply of nitrogen. To this end an abundance of plant food (nitrogen excepted) in not too concentrated solutions, room for the development of roots, exposure to sun and air and protection from wind, rain, dew and excessive heat, have been provided.

An exact account of all nitrogen supplied the plants, aside from that brought to them by the air, was kept, and at the end of the experiment the nitrogen in the whole plant, as well as that left unused in the nutritive solution, was determined. The difference between these two amounts must show the loss or gain in nitrogen. A loss must indicate decomposition of either the organic nitrogen of the seed or plants or of the nitric acid of the nitrates fed, or of both. A gain must represent nitrogen acquired from the air in excess of any lost from either the organic matter of the seed or plant, or from the nitrates of the food.

APPLIANCES, MATERIALS AND METHODS.

Shelter.—In lack of a satisfactory greenhouse, a temporary structure was built with board walls and "three-quarters" roof. The board walls were five feet high at the front and side and higher at the back. At the front and sides the boards were hinged so as to open conveniently. The end gable walls were of canvas, buttoned like an ordinary carriage curtain. The canvas roof opened and closed with roller, somewhat like an ordinary roll awning. The roof is steep and has usually proved an ample protection from the rain, though in a long continued storm the past autumn the rain beat into part of the house so as to seriously interfere with one series of experiments. The canvas had become somewhat worn from use; it is doubtful if the accident would have occurred with new canvas. The house is easy to manage, two minutes are sufficient in which to close and thoroughly secure it at night or before a storm, and still less time is needed to open it.

By this arrangement the plants are grown in the open air in pleasant weather and protected from rain and dew by being kept under cover at night and in rainy weather. In the few cases when the sun's heat was excessive the roof was closed, leaving the sides open. The white canvas allows considerable light to penetrate and more or less air to circulate at all times, and the plants have not suffered materially even when, as occurred more than once during the past summer, it was necessary to keep the house closed for several days at a time. The extreme humidity of the atmosphere which caused the plants to become "drawn" or young plants to "damp off," in gardeners' phrase, is the greatest drawback we have found, and this seemed to be due more to the extraordinary wetness of the past season than to the kind of house employed. Of course it is not such an arrangement as is to be desired, and more satisfactory results are expected in a greenhouse which it is hoped may be built for the purpose.

Pots.—For pots in which to grow the plants, ordinary glass bottles with their bottoms cut off or bell jars with open tops, varying in capacity from one to twenty liters, were employed. They were turned neck downwards, a watch glass was placed over the neck of each and the sand poured in until they were filled within one or two centimetres of the top. Moistening the sand before putting into the jar to avoid too close packing has not been found necessary in our experiments. A glass beaker was placed under the mouth of each pot to catch any solution or sand that might run through. This simple and inexpensive arrangement has served its purpose most satisfactorily. The drainage insures against excess of water and provides circulation of air without the use of glass, pebbles, cotton, tube, for conveying air to the bottom or other arrangements that have been recommended for the purpose.* The pots were enclosed in wooden boxes so constructed as to afford easy access by a door in the side. In our earlier experiments each pot was placed in a box by itself;† in the later work it has been found less expensive and more convenient to put a number of pots, sometimes twelve or more, in one box.

Soil.—Sea sand was freed from coarse particles by sifting, thoroughly washed with water and ignited at a red heat for some time. The sand thus treated gave, in repeated tests, no trace of nitrogen by either the soda-lime or Kjeldahl methods.

Food Supply.—The mineral elements needed for the growth of the plants were added in amounts to make one part or less by weight of dissolved salts in one thousand parts of the solution. Some of the plants received no combined nitrogen except that in the seed; to others nitrates were added, but in such small quantities that the minerals were relatively in excess; to others enough nitrogen was added to make the mixture of plant food correspond more nearly to the composition of the plants.

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* See Hellriegel, Naturwiss., Grundlagen des Ackerbaus, S. 767.

† *Am. Chem. Journal*, 6, 367.

Seed.—Seeds were selected of normal appearance and as uniform in size and weight as practicable. After weighing, each seed was wrapped in filter paper, moistened and allowed to germinate. When the radicles were a centimeter in length or thereabouts, such seeds as germinated well were selected for planting.

Soil Infusions.—The soil infusions were prepared by treating 300 grams of soil taken from near the roots of vigorous plants, with 750 cc. of hydrant water for 24 to 48 hours with occasional shaking. The liquid decanted with the least possible sediment constituted the "soil infusion." The maximum amount of nitrogen found by analysis in 25 cc. of soil infusion was .4 mg.; the minimum, .06 mg.; and the average of 21 analyses of seven kinds of soil infusion gave .26 mg. of nitrogen. This amount is so very small that no account is made of it in the statements of nitrogen supplied.

Water.—The water used in these experiments was prepared by distilling well water, which contained only minute traces of free ammonia and very little so-called albuminoid nitrogen, with the addition of sodium hydroxide and potassium permanganate. The distillate was rejected until Nessler's reagent produced no appreciable coloration. This so-called "nitrogen-free" water actually contained a minute trace of ammonia, the average of several determinations giving .0066 milligram of nitrogen in one liter of water. In only two of the experiments with plants were more than twenty liters of water used, and as 150 liters would by the determinations above cited contain only one milligram of combined nitrogen, error from the use of this water is too small to be taken into account.

Nutritive Solutions.—Four different nutritive solutions were employed. All were so prepared as to contain one part by weight of salts to one hundred parts of solution, the proportions being made as accurate as practicable by the use of chemically pure salts. In those containing nitrogen determinations of the latter were made. The solutions were:—

Phosphoric Acid Solution. This consisted of potassium phosphate, (KH_2PO_4), dissolved in water in the ratio of 1 gram to 100 cc. 1 cc. contained about 5.2 milligrams P_2O_5 and 3.5 milligrams K_2O.

Magnesium Solution. Magnesium sulphate ($MgSO_4$) in water, 1:100. 1 cc. contained 3.8 milligrams MgO and 6.7 milligrams SO_3.

Iron Solution. Ferric chloride, (Fe_2Cl_6), in water, 1:100. 1 cc. contained 3.4 milligrams Fe. and 6.6 milligrams Cl.

Nitrogen (N III) Solution. Calcium nitrate, ($Ca(No_3)_2$), and potassium nitrate, (KNO_3). 1 part of each salt or two of both together to 200 parts water. 1 cc. contained approximately 1.54 milligrams nitrogen and 1.7 milligrams CaO. The "N III" solution was always supplied to the plants from the same 25 cc. pipette, which actually delivered at 16°C, 24.895 cc. The mean of several analyses gave 37.66 milligrams of nitrogen in this quantity of the nitrogen solution.

When the solutions were applied, enough water was added to make the solution in the sand contain less than one part of salt to one thousand parts of water.

Preparation for Analysis.—At the end of the experiment the aerial portions of the plant were harvested and the roots separated from the sand by washing with water. The separation is easily effected, and but comparatively little water is required if the harvesting is done before the plants are too much withered and the washing follows before the roots are dried. The nitrates of the "residual solution" are first removed with water. The washings are evaporated for the determination of nitrogen in the residual solution. After the nitrates are supposed to be completely washed out, another extraction is made in each case, and the water evaporated and tested for nitrates by the same quantitative method as for the regular determination. The pots serve conveniently as funnels, and as repeated tests have shown, but a comparatively small amount of water is needed to wash out the nitrates completely. The pots are then supported obliquely with the surface downwards and the sand washed out by a stream of water. The roots, which suffer very little loss in this process, are dried and the nitrogen is determined in them as in the tops.

Estimation of Number of Root Tubercles.—The tubercles vary from the size of a pin-head to that of a small pea or larger, and tend to grow together in masses, so that it is practically impossible to count them, and even if counted the number would mean but little for purposes of comparison because of the variations in size. An arbitrary estimate of their amount was, however, made at the time of the separation of the roots from the sand by washing. As this, of course, preceded the weighings and analyses, the observer was free from bias in judging of the abundance of the tubercles. When the number was so small that they could be readily counted, the roots were spoken of as having "few tubercles;" more than could be readily counted were spoken of as a "fair number," or, when they were present in great abundance, the expression "a large number" was used. The estimates are relative and depend somewhat upon the amount of roots, for what would be a large number with a small root development would be a "fair number" when distributed over a large amount of roots. This arbitrary classification, which presented but little difficulty in practice, is used in the descriptions and tables beyond.

METHODS OF ANALYSIS.

Nitrogen in Seeds.—A considerable quantity of the seed was ground, and samples from it analyzed by either the soda-lime or the Kjeldahl method or both. The average of these analyses was assumed to represent the percentage of nitrogen in the seeds of the same lot which were sown in the experiment.

Nitrogen in Plants.—In the earlier work the analysis of the plants was made by grinding and estimating nitrogen by the soda-lime method in samples of the whole and multiplying in the usual way. In the experiments here described, unless the plants have weighed more than twenty-five or thirty grams, they were put into one or more Kjeldahl digesting flasks and treated directly without grinding. In an ordinary digester no difficulty was found in handling ten grams, and as much as twenty grams have been successfully used. The only trouble is from frothing, which can be prevented by slow heating. After digesting, the solution was diluted and divided into aliquot parts for distilling. By thus determining the nitrogen in the entire sample, the labor was reduced and as no sampling was necessary the accuracy was increased.

Nitrogen in Nutritive Solutions.—The nitrogen in the nutritive solutions and in the residual solutions extracted from the sand at the end of the experiment was determined by the method of Schulze-Tiemann. Properly manipulated this method gives very accurate results, as is shown by an investigation of the method and its sources of error, the results of which are stated in brief in another part of this report and will be printed in detail elsewhere.

NOTES ON THE CULTURE AND THE GROWTH OF THE PLANTS.

Like other experimenters, we have found it feasible, with proper care, to grow plants in sand culture to compare favorably with the same varieties of plants grown in the field or garden. Different species of plants require somewhat different treatment, which can be learned only by experience. On the whole our plants have succeeded better in cool than in hot weather, perhaps because of the difficulty of keeping the soil (sand) cool when the weather is hot. The tendency of peas, especially young vines, to mildew in hot, damp weather has been very troublesome. In a long continued wet period last July over fifty young pea plants, in gardeners' phrase, "damped off." Numerous drawbacks of this and similar kinds have been experienced. Of 267 experiments undertaken only about 100 have proven wholly successful. Still we deem sand culture decidedly practicable and useful for the plants we have worked with.

East Hartford Early Peas.—This is an early, dwarf variety prized by market gardeners in this vicinity. In ordinary culture the vines grow from two and one-half to three feet in height and in rich soil are somewhat taller. In our experiments many of the plants attained the normal size and some were unusually large. In numerous cases peculiarities of growth demand attention. Although these peculiarities were no more marked in the plants without than in those with nitrogen in the food supplied, it will be well for convenience to consider especially the plants that were not fed with nitrogen aside from that contained in the seed. Usually the growth of these plants was reasonably uniform and apparently normal until they attained a height of twelve or fifteen inches. From this stage one of three things happened, leading to the following classification:

(1) A "starvation" period, analagous to that described by Hellriegel,* began, in which the healthy green color of the leaves gave place to a sickly yellow, the plants blossomed and developed small and imperfect peas or none at all and then died. The plants manifesting this demeanor had very few or, more commonly, no root tubercles. Experiment No. 137† illustrates this. Three seeds weighing together .96 gram gave rise to two plants fifteen inches in height and one ten inches in height and bearing one pod containing one pea. The dry plants weighed .97 gram

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* Hellriegel und Wilfarth, loc. cit.

† See tables at end of this article.

and contained 11 milligrams less nitrogen than was contained in the seed. There were no root tubercles.

Sometimes the plants recovered from this starvation stage and developed so as to be grouped with those of the other classes.

(2) The plants retained their healthy appearance, blossomed, developed a few seeds, rarely more than one or two, and then died without attaining a greater growth. Root tubercles were usually found in greater or less abundance in this class. Experiment No. 119 is a case in point. Two seeds weighing .53 gram gave rise to two plants 18 inches high, bearing three pods and three peas. The dry plant weighed 1.57 grams and contained 31 milligrams more nitrogen than was in the seed used. There were a large number of root tubercles.

(3) Other plants kept on growing, were apparently normal and frequently attained a height of four or more feet before blossoming. Usually these plants bore a fair number of perfect seeds.

In the experiments with East Hartford Early Peas, from two to five plants were grown in a single pot, but in no case did all of the plants of an experiment attain this large growth. Thus Experiment No. 136 had four plants, of which three might be reckoned with the second and one with the third class. Four seeds weighing .94 gram gave rise to three plants 14 inches high bearing three pods and containing three peas, and one plant 58 inches in height bearing two pods and nine peas. The first three plants were ripe July 1st, the other kept on growing till August 15th. The four plants weighed 7.06 grams and contained 243 milligrams more nitrogen than was in the seed used. Root tubercles were abundant.

Examples of all three of these phases of growth sometimes occurred in the same pot. As a rule the larger the plant the greater was the number of root tubercles found upon it.

The last two phases of growth were even more noticeable in the experiments in which nitrates were supplied to the plants. Occasionally the first or starved form appeared. Usually the plants were relatively taller and contained higher percentages of nitrogen than the ones not fed with nitrates. In several cases these so called "dwarf peas" attained a height of over eight feet.

Experiment No. 148 illustrates all three phases of growth in a case in which nitrogen was supplied in nitrates. Four seeds gave rise to four plants, 16, 35, 42 and 83 inches high respectively. The last plant had 11 peas, the other three 13. In this case tubercles were abundant on the large plants.

Champion of England Peas.—As a rule these peas grew much more uniformly than the dwarf peas, though in a single pot they often varied two or more feet in height. The different phases of growth were less marked than with the dwarf peas.

Alfalfa.—We have found but little difficulty in growing alfalfa in sand; even plants not fed with nitrogen but supplied with plenty of mineral food have developed normally and have at no time shown any very marked starvation stage of growth. Two experiments will illustrate the vigor of growth with and without a supply of nitrogen in the food.

In Experiment No. 109, three plants to which no nitrogen was fed other than the small fraction of a milligram contained in the seed and soil infusion, had sixteen branches averaging 15 inches in height, and weighed, air dry, 3.22 grams. They obtained from the atmosphere 137 milligrams of nitrogen.

In Experiment No. 113, one plant fed with nitrogen in the form of nitrates had 35 branches, averaging 20 inches in height; weighed 12.9 grams and contained when mature 382 milligrams of nitrogen more than was supplied to it in seed and nutritive solution.

Oats and Corn.—Oats grew well, better than field oats average in this climate. The corn grew fairly well but did not fruit fully. Lack of fertilization from insufficiency of pollen seemed to be the chief trouble. Owing to its tendency to great root development, pots of three to five gallons capacity were used.

THE EXPERIMENTS HERE REPORTED.

The experiments here described may be divided into the following series:

Series.	Year.	Kind of Plants.	No. of Exp'ts.	No. of Plants.
VII.	1888.	Champion of England Peas, - -	25	64
VIII.	1888–9.	Alfalfa, - - - - - - -	5	9
IX.	1888.	Corn, - - - - - - -	8	15
X.	1889.	East Hartford Early Peas, - - -	34	104
XI.	1889.	Champion of England Peas, - -	16	70
XII.	1889.	Oats, - - - - - - - -	11	66
XIII.	1889.	Corn, - - - - - - -	18	35
		Total, - - - - - -	117	363

SPECIMEN EXPERIMENTS.

The methods may be illustrated by a description of two typical experiments.

Experiment No. 135, with East Hartford Early Peas, Series of 1889.—The pot used in this experiment held 3 kilograms (six and a half pounds) of sand. This was placed in the pot April 10th, and the same day four well sprouted peas, which had weighed before sprouting 0.998 gram (15 grains) were planted. When planted they were fed with mineral salts, without combined nitrogen, in such amount that the ratio of salts to water was about 1 to 1500. They were again fed with minerals on May 10th. During the period of growth, water was given them 41 times, 6.6 liters (somewhat over 6 qts.) being used. No soil infusion was given.

About the middle of June two of the plants had stopped growing. These were not more than one foot in height, and when harvested were found to have no root tubercles. The other two kept growing, though not equally well, till about July 9th, when they were harvested. At this time one of the plants was two and one-half and the other a little over five feet in height. Both had root tubercles. The four plants had 9 pods and 15 peas. The weight of the partly dried fruit and vines was 7.97 grams (123 grains). The roots, freed as far as practicable from sand, weighed 1.27 grams (20 grains), making the total weight of the four plants 9.24 grams (143 grains). The plant altogether contained 237.1 milligrams (3.65 grains) of nitrogen. The seed, as shown by analysis of similar ones, contained 39.9 milligrams nitrogen. The balance sheet of the experiment is as follows:

Nitrogen fed in the seed, - - -	39.9 milligrams	(0.61 grains).
Nitrogen found in plants, - - -	237.1 milligrams	(3.65 grains).
Gain, - - - - - -	197.2 milligrams	(3.04 grains).

The gain of nitrogen during the growth was thus 197.2 milligrams (3.04 grains).

In a large number of experiments, the plants have had no root tubercles. In nearly every case of this sort there has been more or less loss, instead of gain, of nitrogen. The natural inference is, that in the experiment just described, all the gain of nitrogen was made by the larger plants which had the root tubercles, and that they thus actually acquired from the air not only 197.2 milligrams (3.04 grains) of nitrogen which is counted as gain, but enough besides to offset more or less loss where there were no tubercles.

Experiment No. 165, with Champion of England Peas.—Six kilograms of sand were placed in the pot April 15th, and the same day 6 peas, weighing 2.3 grams (35 grains), were planted. The plants were fed with minerals and with nitrogen in the form of calcium and potassium nitrates, when the seeds were planted, and on May 15th, June 20th, and June 22d. On May 11th and 20th, 25 cc. of an infusion of garden soil in which peas were growing were added. During the whole period of growth the plants were watered 46 times, 13.9 liters (about 13 quarts) water being used. The plants had finished their growth and were nearly ripe on July 9th, when they were harvested. The notes taken at the harvesting were as follows:

Six Plants Grown in Sand.

HEIGHT.	NO. OF PODS AND PEAS.	
	Pods.	Peas.
3 feet 8 inches,	1	2
4 " 9 "	3	5
5 " 10 "	4	7
4 " 0 "	2	6
5 " 9 "	3	7
5 " 6 "	2	7
Total,	15	34

The roots had a good many tubercles, which were pretty evenly distributed. The partly dried vines and fruit weighed 24.85 grams (383 grains), the roots freed from sand as completely as practicable, 7.87 grams (121 grains), making the total weight of the six plants 32.72 grams (504 grains). These contained 694.5 milligrams (10.70 grains) nitrogen. The soil (sand) at the end of the experiment contained 23.5 milligrams (.36 grains) nitrogen as nitrate. The balance sheet is as follows:

Nitrogen fed in the seed,	105.1 mg.		
Nitrogen fed in solution,	447.7 mg.		
		552.8 mg.	(8.51 grains).
Nitrogen found in soil,	23.5 mg.		
Nitrogen found in plants,	694.5 mg.		
		718.0 mg.	(11.06 grains).
Gain in nitrogen,		165.2 mg.	(2.55 grains).

The principal statistics of the experiments are given in the tables at the end of this article.

ABSORPTION OF COMBINED NITROGEN FROM THE AIR.

Tests made in connection with previous experiments here failed to give indications of any considerable absorption of ammonia or nitric acid by nutritive solutions in sand exposed to the air under conditions similar to those of the experiment and implied that no considerable quantities of combined nitrogen from the air could have been purveyed to the plants by the solutions.* As a further precaution the following tests were made in connection with the experiments here reported. Pots were filled with sand and nutritive solutions (see descriptions of nutritive solutions above) were added as in the regular experiments, but no seeds were sown. In two cases dilute acid was used instead of the nutritive solutions. They were put into the plant-house July 11th and brought to the laboratory for analysis October 20th, 1889, and were thus exposed for over three months to the same atmospheric conditions as those in which the plants were grown. They were watered often enough to keep the sand apparently as moist as that in which the plants were grown, 1100 cc. of water being used for each pot. Eight such tests were made, in four series, as follows:

A. With Dilute Sulphuric Acid.—Two pots, Nos. 65 and 66, each holding 1½ kg. of sand, were supplied each with 10 cc. of dilute sulphuric acid containing, approximately, 30 mg. of H_2SO_4 in one cc. At the end of the trial the solutions were extracted and tested for ammonia and nitric acid. Each gave by distillation and titration approximately one milligram of ammonia and no trace of nitric acid by the Tiemann-Schulze method; thus indicating that a minute quantity of ammonia and no appreciable amount of nitric (or nitrous) acid had been absorbed from the air and fixed by the acid solution.

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*The following is from the discussion of the experiments referred to:

"During the course of the experiments of the second series, a number of pots with sand and solutions like those in which the plants grew were kept alongside the latter. The solutions at the end of the experiments revealed only such minute quantities of combined nitrogen as are commonly found in natural waters exposed to the air. That these solutions, without plants, had so little of nitrogen compounds is, however, no proof that the solutions in which the plants grew might not have yielded to the plants some of the ammonia which they were continually absorbing, and which, if not somehow seized upon, would escape by virtue of its tension. The fact that the solutions in which the plants grew were neutral or faintly alkaline, would, however, make the hypothesis of any considerable absorption of ammonia apparently improbable. It is worth noting, too, that the residual solutions at the end of the experiment contained only the minutest qnantities of ammonia discernible by aid of Nessler's reagent."—*Am. Chem. Journal*, 6, 376.

B. With Nutritive Solutions Containing No Nitrates.—Two pots, Nos. 67 and 68, each holding 1½ kg. of sand, were supplied each with 15 cc. phosphoric acid solution, 10 cc. of the magnesium solution and 1 cc. of the iron solution used in the experiments. Extracted and tested as above, at the end of the trial neither yielded any appreciable quantity of ammonia or nitric acid.

C. With Nutritive Solutions Including Nitrates.—Two pots, Nos. 69 and 70, each holding 1½ kg. of sand, received each 15 cc. of the phosphoric acid solution, 10 cc. of magnesium solution, 1 cc. of the iron solution, and 25 cc. N.III solution (calcium and potassium nitrates), used for the experiments. At the end of the trial both were extracted and tested as was done with the previous series. In neither was any appreciable quantity of ammonia found. Each had received 37.66 mg. of nitrogen in the "N.III" solution. No. 69 gave 36.66 and No. 70, 36.30 mg. of nitrogen as nitric acid or other nitrogen compound by the Tiemann-Schulze method. There was, then, no indication of absorption of ammonia, but very small quantities of nitrates were lost.

D. With Nutritive Solutions, Including Nitrates and Pea Soil Infusion.—Two pots, No. 71 and 72, each holding 2 kg. of sand, received each 15 cc. of phosphoric solution, 10 cc. magnesium solution, 1 cc. iron solution, and 25 cc. N.III solution and 25 cc. of pea soil infusion. At the end of the trial neither gave any appreciable quantity of ammonia. Each had received 37.66 mg. of nitrogen in nitrates. In No. 70, 36.30 and in No. 71, 36.84 mg. of nitrogen was obtained by the Tiemann-Schulze method. The results were, therefore, essentially the same as those in series C.

It appears then that no considerable amount of combined nitrogen was acquired by either the nutritive solutions or by an acid solution in sand under the conditions in which the plants of the experiments were grown. Of course the solutions in which the plants grew were subject to changes different from those to which the solutions in these blank trials were exposed, but it is difficult to conceive how either the sand or the solutions in which the plants grew or the sand and solutions together could have absorbed and yielded to the plants more combined nitrogen either in the form of ammonia, nitrates or otherwise, than would be acquired by the nutritive solutions or a dilute acid solution without plants but otherwise subject to the same conditions.

The natural inferences are that:

(1) No considerable quantity of combined nitrogen was derived from the air and yielded to the plant by the medium in which the plant grew.

(2) The slight loss of nitrates may possibly indicate decomposition, but it is small, varying from .8 to 1.3 milligrams, and may very likely be due, in part at least, to experimental errors.

DISCUSSION OF RESULTS OF EXPERIMENTS.

The principal statistics of the experiments are collated in Tables 7 to 13 at the end of this article, and may be summarized as in Tables 1, 2, 3, 4 and 5, which follow here.

As previously explained the estimates of the numbers of tubercles were made before the analysis of the plants, and thus the observer was free from bias.

While it is not practicable to give more than a relative idea of their abundance, this grouping them into few, fair number, and large number, presented but little difficulty.

TABLE 1.

Experiments with Oats, Series XII., 1889.

SUMMARY OF RESULTS.

	No. of Experiments.	No. of Plants in Experiments.	Average Gain (or Loss—) of Nitrogen.
			Mg.
Not fed nitrogen except in seed, - - - - -	4	24	2.3
Fed 304 milligrams nitrogen as calcium and potassium nitrates, - - - - - - - -	3	18	—101.5
Fed 607 milligrams nitrogen as calcium and potassium nitrates, - - - - - - - -	3	18	—207.8
Total, - - - - - - - - -	10	60	

Table 1 epitomizes the results with oats. The experiments are arranged in accordance with the amounts of combined nitrogen fed. No tubercles were found upon the roots. It will be noticed that plants not fed with nitrates made a very slight gain (the largest gain was 3.1 and the smallest 1.6 milligrams), while in each case where nitrates were supplied there was a considerable loss and that the loss increased with the amount of nitrates added. Doubling the nitrogen fed doubled the loss of nitrogen.

TABLE 2.

Experiments with Corn, 1888–1889.

SUMMARY OF RESULTS.

	No. of Experiments.	No. of Plants in Experiments.	Average Gain (or Loss —) of Nitrogen.
			Mg.
Not fed nitrogen except in seed, Series IX., 1888, - -	4	7	5.6
Not fed nitrogen except in seed, Series XIII., 1889, -	6	12	9.5
Fed 114 milligrams nitrogen as nitrates, Series IX., 1888,	4	8	15.6
Fed 607 milligrams nitrogen as nitrates, Series XIII., 1889,	6	11	— 88.4
Fed 1518 milligrams nitrogen as nitrates, Series XIII., 1889,	6	12	—236.8
Total, - - - - - - - - - -	26	50	

Table 2 epitomizes the results with corn. The experiments are arranged in accordance with the amount of combined nitrogen fed. No tubercles were found upon the roots. It will be noticed that plants not fed with nitrates and those fed with the smallest proportion of nitrates made a very slight gain, while in the other cases where nitrates were supplied there was a considerable loss and that the loss increased with the amount of nitrates added.

TABLE 3.

Experiments with Alfalfa, Series VIII., 1888–1889.

SUMMARY OF RESULTS.

	Root Tubercles.	No. of Experiments.	No. of Plants in Experiments.	Average Gain of Nitrogen.
				Mg.
Not fed with nitrogen except that in seed, - - - - - - -	None, - -	—	—	—
	Few, - -	—	—	—
	Fair number,	1	3	137.5
	Large number,	—	—	—
	Total, -	1	3	
Fed with 340 milligrams nitrogen as calcium and potassium nitrates, - -	None, - -	—	—	
	Few, - -	3	4	84.0
	Fair number,	—	—	—
	Large number,	1	1	382.2
	Total, -	4	5	

Table 3 summarizes the results with alfalfa. As explained in Table 10 beyond, the plants made but little growth the first season and a number died. Those which survived made a very satisfactory growth the second season. All the plants had root tubercles.

TABLE 4.—*Experiments with Peas.*

SUMMARY OF RESULTS.

	Root Tubercles.	No. of Experiments.	No. of Plants in Experiments.	Average Gain (or Loss—) of Nitrogen.
				Mg.
CHAMPION OF ENGLAND PEAS. *Series VII., 1888.*				
Not fed with nitrogen except that in Seed, - - - - - -	None, - -	6	13	—9.8
	Few, - -	1	3	—1.7
	Fair number,	1	3	85.6
	Large number,	1	3	116.7
	Total, -	9	22	
Fed with 76 to 252 milligrams nitrogen as calcium and potassium nitrates in addition to that in seed, - - -	None, - -	6	13	—22.7
	Few, - -	4	11	— 3.1
	Fair number,	3	9	19.7
	Large number,	3	9	49.0
	Total, -	16	42	
Series XI., 1889.				
Not fed with nitrogen except that in seed, - - - - - -	None, - -	2	6	—9.0
	Few, - -	1	4	—13.5
	Fair number,	2	8	69.4
	Large number,	1	4	78.7
	Total, -	6	22	
Fed with 152 to 448 milligrams nitrogen as calcium and potassium nitrates in addition to that in seed, - - -	None, - -	—	—	—
	Few, - -	2	10	26.5
	Fair number,	1	4	60.2
	Large number,	7	34	149.6
	Total, -	10	48	
EAST HARTFORD EARLY PEAS. *Series X., 1889.*				
Not fed with nitrogen except that in seed, - - - - - -	None, - -	2	4	—9.6
	Few, - -	5	14	0.1
	Fair number,	1	4	28.7
	Large number,	8	23	72.9
	Total, -	16	45	
Fed with 76 to 228 milligrams nitrogen as calcium and potassium nitrates in addition to that in seed, - - -	None, - -	—	—	—
	Few, - -	6	18	—5.6
	Fair number,	3	11	26.4
	Large number,	8	26	74.5
	Total, -	17	55	

Table 4 summarizes the results with peas. The experiments are arranged in accordance with the number of root tubercles observed at the time of harvest.

TABLE 5.

Experiments with Peas and Alfalfa, 1888–1889.

CONDENSED SUMMARY OF RESULTS AND AVERAGES.

Root Tubercles.		Without Nitrogen in Nutritive Solutions.			With Nitrogen in Nutritive Solutions.			Total.		
		No of Experiments.	No. of Plants in Experiments.	Average Gain (or Loss—) of Nitrogen.	No. of Experiments.	No. of Plants in Experiments.	Average Gain (or Loss—) of Nitrogen.	No. of Experiments.	No. of Plants in Experiments.	Average Gain (or Loss—) of Nitrogen.
				Mg.			Mg.			Mg.
Peas.	None, - - - -	10	23	—9.6	6	13	—22.7	16	36	—14.5
	Few, - - - -	7	21	—2.1	12	39	0.6	19	60	—0.4
	Fair number, -	4	15	63.3	7	24	28.4	11	39	41.1
	Large number, -	10	30	77.9	18	69	99.5	28	99	91.7
Alfalfa.	None, - - - -	—		—	—	—	—	—	—	—
	Few, - - - -	—	—	—	3	4	84.0	3	4	84.0
	Fair number, -	1	3	137.5	—	—	—	1	3	137.5
	Large number, -	—	—	—	1	1	382.2	1	1	382.2

In Table 5 a condensed summary of Tables 3 and 4 is given. The results with Champion of England and East Hartford Early Peas are arranged together.

LOSS OF NITROGEN.

In many of the experiments, instead of gain of nitrogen a decided loss was observed. With peas the loss appears in every case in which there were no root tubercles and in many of the cases in which only a "few" tubercles were developed. (See Table 4 above and detailed tables at the end of this article.) This loss of nitrogen manifested itself whether the plants were fed with nitrogen or not, though it was larger with the nitrogen-fed plants than those which received no nitrates.

With the oats and corn (see Tables 1 and 2 above and detailed tables at the end of article) most of the nitrogen-fed plants showed a large loss, while with those which had no nitrates there was a slight gain.

Two sources of loss of nitrogen suggest themselves, namely, decomposition of the organic matter of seed or plant and decomposition of nitrates fed. Loss from decomposition of seed or of seed and plants accords with the results of observations in experiments at this place, from the report* of which the following table is copied. In each of the thirteen experiments from five to twenty-three peas were germinated in a germinating apparatus or in sand and allowed to grow for a longer or shorter period in water or sand without artificial food supply. The difference between the nitrogen in the seed and that found at the end of the experiment in the plants and the medium in which they grew is the nitrogen lost.

Experiments on the Loss of Nitrogen during Germination and Early Growth.

Conditions of Germination and Growth of Peas.	Experiments.		Time of Germination and Growth.	Nitrogen Lost, in per cent. of Total in Seed at beginning of Experiments.
	Series.	No.		
Water Culture.				
Seeds germinated and then suspended with roots immersed in pure water. Experiments in open air,	III.	3	8 days.	8.4 per cent.
		1	10 "	9.8 "
		2	15 "	1.5 "
Sand Culture.				
Seeds germinated and grown in sand. Experiments in open air,	IV.	6	6 "	5.9 "
		7	10 "	10.6 "
		8	14 "	15.1 "
Seeds germinated and then transferred to sand, Experiments in greenhouse,	V.	9	18 "	7.3 "
		10	28 "	12.4 "
		11	52 "	16.3 "
Seeds germinated and then transferred to sand, Experiments in dwelling-house,	VI.	12	29 "	8.2 "
		13	42 "	11.0 "

The results thus cited indicate that germination and early growth of peas are, or at any rate may be, accompanied by greater or less loss of nitrogen. In the experiments herewith reported upon there was an average loss of about 9 milligrams of nitrogen with the peas (Series VII. and IX.) which were not nitrogen-fed and which failed to develop root tubercles. In the peas of Series VII. and IX. which were fed with nitrates there was an average

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*On the loss of nitrogen by plants during germination and growth, W. O. Atwater and E. W. Rockwood, *Am. Chem. Journal*, 8, 327.

loss of about 23 milligrams in the plants without root tubercles. The loss with the nitrogen-fed peas was two and one-half times as great as with those not nitrogen-fed.

With oats and corn, fed with very little or with no nitrogen, there is no apparent loss, but a small gain instead. On the other hand, with the nitrogen-fed oats and corn the loss of nitrogen is marked, increases with the quantity of nitrogen supplied and is much larger than with the peas.

This loss of nitrogen gives added force to the suggestion made in the report* of the earlier work here that if nitrogen escaped in some of the trials it may have done so in the other cases as well. If this be true the results are all inaccurate as indications of the actual atmospheric nitrogen acquired and the plants must really have obtained more nitrogen than the figures here imply.

These experiments do not tell to what extent the loss observed with the oats and corn and with the peas which had no root tubercles was from the seed and to what extent from the nitrates; whether, as would seem most likely, it was due to the action of microbes or what connection there may be between plants of different species and the loss of nitrogen. These and kindred questions must remain for future research to decide.

ACQUISITION OF NITROGEN FROM THE AIR.

That the legumes experimented with obtained large amounts of nitrogen from the air is abundantly shown by the facts cited in the tables. The evidence coincides exactly with that of the previous experiments here and the later ones by Hellriegel and others and is plain and unmistakable. Peas of a small, early variety (East Hartford Early), grown in sand, with no nitrogenous food except that in the seed and what they were able to acquire from the atmosphere, attained a hight of over five feet. With nitrogen supplied in the nutritive solutions they reached a hight of over eight feet. The quantities of atmospheric nitrogen obtained by the pea and alfalfa plants (Tables 3, 4 and 5 above) were in many cases very large.

Whether the nitrogen thus obtained from the air was free or combined nitrogen these experiments do not absolutely prove. But the quantities obtained are so very large as to leave little doubt that it is free nitrogen. That any considerable quantity of combined nitrogen could have been taken from the atmosphere by the nutritive solutions and soil and thus conveyed to the plants, would seem from the consideration cited in connection with the descriptions of "blank" tests above, to be out of the question, nor does it seem at all reasonable to assume the possibility of so much combined nitrogen being absorbed by the foliage of the plants.* The experiments of Hellriegel already referred to, in which plants grown in confined air without combined nitrogen but with root tubercles acquire considerable quantities of nitrogen, would seem to put the acquisition of free nitrogen by plants beyond question. This special subject, however, demands further investigation. Plans for its study are now being made.

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*Loc. cit., p. 403.

One special point calls for notice here. In general, the smaller plants with fewer seeds show a loss of nitrogen, while the larger, stronger plants with more normal development show the gain. In many of the experiments which brought the gains of nitrogen some of the plants were large and had a number of well developed seeds while others were small and had few seeds. The natural inferences are that the gain of nitrogen was made by the well developed plants; that the actual gain was larger than the apparent gain; and that this actual gain by the well developed plants covered the apparent gain in the whole experiment plus enough to make up for any losses from decomposition of seeds of both the vigorous and the weaker plants, from decomposition of nitrates and from other causes. In other words, it seems probable that the vigorous plants had to make up for the losses of the weaker ones, and hence the actual gain by normal plants is larger than the statistics of these experiments show.

Thus in the experiments with East Hartford Early Peas it was observed that, as a rule, unless the plants not supplied with nitrates made a growth of at least 14 inches and developed more than one pea to a vine, the pea was a small one, and the results indicated a loss of nitrogen. The following data from Table 9 will serve as illustrations:

No. 120—1 plant, 15 inches high; 1 pod, 1 pea; loss, 7.7 mg. nitrogen.
No. 128—3 plants, 12 inches high; 3 pods, 3 peas; loss, 3.6 mg. nitrogen.
No. 137—3 plants, 10-15 inches high; 1 pod, 1 pea; loss, 11.4 mg. nitrogen.
No. 138—4 plants, 12-27 inches high; 2 pods, 2 peas; loss, 3.9 mg. nitrogen.
No. 140—4 plants, 9-12 inches high; 4 pods, 4 peas; loss, 2.4 mg. nitrogen.

In only one case (No. 127; 3 plants, 12-15 in. high; 3 pods, 3 peas; gain, 26.5 mg. nitrogen,) did the plants not nitrogen-fed

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*See discussion of this subject in description of previous experiments in this place, *Am. Chem. Journal*, 6, p. 378.

show a gain without producing more than an average of one pea per vine. In this case the 15-inch plant had two peas, and it seems at least reasonable to question whether this plant did not make the gain.

In nearly all, if not all, of the experiments with East Hartford Early Peas that have shown a gain of nitrogen some of the plants have been small and with no peas or at most only one. It seems reasonable to suppose from the above cited trials that the apparent gain may have been due to the large, strong plants, and that these latter gained enough to offset the loss by the weaker plants and provide, in addition, for the apparent gain of the whole experiment. The following from table above cited will illustrate.

No. 136 had four plants; three 14 inches; one 58 inches high and bearing 5 pods with 12 peas. The estimated gain of nitrogen was 242.9 milligrams. In this case the three 14 inch plants bore 3 pods with three peas, and the large plant 2 pods with 9 peas. The loss almost uniformly observed with the small plants bearing few peas in other experiments makes it possible that the small plants did not hold their own; that, in other words, taken by themselves they lost nitrogen. If this be so, the gain of at least one-fourth of a gram must have been made by the one large plant. The same may be said of No. 135. Two of the plants were small and bore practically no fruit. The apparent gain was about one-fifth gram. The inference is that the well developed plants made the whole gain of nitrogen. In most of the experiments there was more or less of this difference of growth, and to distribute the gain evenly to all of the plants of a single experiment would obviously be erroneous. Indeed, there is little room for doubt that the apparent gain of the large plants would have been materially greater than that of the whole experiment, if the weak plants had not been present.

Why, in the same pot, under apparently the same conditions, one plant should thrive so much better than others; why one should grow luxuriantly while others starve, is difficult to understand. That this was the case in the experiments with East Hartford Early Peas is evident. The growth of Champion of England Peas has been much more uniform. The different plants in the same pot differ but little from each other in apparent vigor of growth.

The plan for the next experiments here will include pots with only one plant in each, and thus eliminate the difficulties noticed in the experiments with East Hartford Early Peas, and to a greater or less extent in those with other plants.

SPECIES OF PLANTS WHICH ACQUIRE ATMOSPHERIC NITROGEN IN LARGE QUANTITIES.

In our experiments, peas and alfalfa have gained large quantities of nitrogen from the air. The corn in Series IX. acquired small quantities of nitrogen from the air, but this acquisition was not substantiated with experiments of corn and oats of Series XII. and XIII. The reasons for this difference of results with the corn and oats demand further experiment for their explanation.

Hellriegel*, Wolff†, Bréal‡ and others have found peas, lupines, serradella, beans, and in all probability (Wolff) clover to acquire atmospheric nitrogen, while the cereals, buckwheat and potatoes have failed to give positive evidence of so doing. The facts thus attested accord with manifold observations of field practice in implying that leguminous plants, or at least some species of legumes, possess in high degree the power to obtain nitrogen from the air.

RELATION BETWEEN ROOT TUBERCLES AND GAIN OF NITROGEN.

Examination of the detailed tabular statements of results of 80 experiments with peas and alfalfa here described shows that in every case, without exception, where there were no root tubercles there was loss of nitrogen; where there were "few" tubercles there was sometimes a slight loss of nitrogen, at other times a slight gain; with a "fair number" of tubercles there was a decided gain; where there was a "large number" of tubercles the gain of nitrogen was very large.

In the experiments with corn and oats, which had no tubercles, there was, in a few cases, a very slight gain of nitrogen, in others a loss, generally very large. The explanation of this behavior of the cereal plants must await further investigation. Meanwhile it is sufficient to say the leguminous plants have root tubercles and acquire large quantities of nitrogen.

The nature and functions of root tubercles, though now actively discussed, are not fully understood. While there is as yet no positive proof that the root tubercles or the microbes which appear to be connected with them are the cause of the gain of nitrogen, the fact that there is a connection between the root tubercles and the amount of nitrogen acquired by the plants from the air is unmistakable.

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* Loc. cit. † *Landw. Jahrb.*, 1887, s. 659. ‡ *Compt. rend.*, 109, p. 670.

It seems probable that this relation holds in field as in pot culture. The past season the Station grew half an acre of cowpeas, which yielded at the rate of about eight tons of green fodder per acre. In some ten different places in the field the roots were examined and found to be covered with tubercles of considerable size. Some were as large as peas. At one end of the field, where the yield was relatively light, the roots had less tubercles than elsewhere, and in general where the growth was heaviest the tubercles seemed to be most abundant.

Our experiments thus confirm the important observation, first made by Hellriegel, of the connection between root tubercles and acquisition of nitrogen and support the belief that the faculty of obtaining atmospheric nitrogen is especially characteristic of some if not all species of legumes.

RELATION BETWEEN SOIL INFUSIONS AND ROOT TUBERCLES.

As may be seen from Table 6, herewith, the addition of soil infusion seemed to make infection much more certain, but a large number of the plants had an abundance of root tubercles without the infusions although grown in sterilized sand supplied with water that had been distilled and solutions prepared with that water. That this should be the case is not at all surprising if, as seems probable, the development of the tubercles is due to bacteria or other micro-organisms. These experiments were conducted near cultivated ground, a garden, where such organisms or their germs might naturally be abundant in the air and find their way to the pots in which the plants were cultivated.

A possible explanation of this greater abundance in the nitrogen-fed plants may be that these plants are sustained by the nitrogen supplied until they become infected and are enabled to attain the nitrogen from the air.

Table 6 recapitulates the results of 69 experiments, 64 with peas (those with bacteria cultures are omitted) and 5 with alfalfa. The first group contains 32 experiments with peas and alfalfa to which no soil infusions were added. The last column shows the percentage of experiments in which tubercles were found at harvest. The plants in 47 per cent. of the experiments had a "large number" of tubercles, notwithstanding they received no soil infusion. The second group contains 37 experiments with alfalfa and peas, all of which were treated with soil infusion. In only 43 per cent. of these were a "large number" of tubercles found.

TABLE 6.

Relation between Soil Infusion and Tubercles.

NUMBERS OF EXPERIMENTS IN WHICH THERE WERE NO ROOT TUBERCLES, A FEW, A FAIR NUMBER, OR A LARGE NUMBER, AS ESTIMATED AT HARVESTING.

	Champion of England Peas, Series VII., 1888.	Alfalfa, Series VIII.	East Hartford Early Peas, Series X., 1889.	Champion of England Peas, Series XI., 1889.	Total No. of Experiments.	Per Cent. of Total No. of Experiments.
Without Soil Infusion.						
Experiments with no tubercles, - - -	2	—	1	2	5	15.6
" " few tubercles, - - -	2	2	2	2	8	25.0
" " fair number of tubercles,	1	—	2	1	4	12.5
" " large number of tubercles,	1	—	11	3	15	46.9
Total number of experiments, - - -	6	2	16	8	32	100.0
With Soil Infusion.						
Experiments with no tubercles, - - -	0	—	1	0	1	2.7
" " few tubercles, - - -	2	1	9	1	13	35.1
" " fair number of tubercles,	2	1	2	2	7	18.9
" " large number of tubercles,	4	1	6	5	16	43.3
Total number of experiments, - - -	8	3	18	8	37	100.0

SUMMARY.

1. Peas, alfalfa, serradella and lupine certainly, clover in all probability, cow peas presumably, and perhaps leguminous plants in general, are able to acquire large quantities of nitrogen from the air during their period of growth.

2. There is scarcely room to doubt that the free nitrogen of the air is thus acquired by plants.

3. Without root tubercles there was in no case any large gain and with them there was uniformly more or less gain of nitrogen from the air. As a rule, the greater the abundance of root tubercles in these experiments the larger and more vigorous were the plants and the greater was the amount of atmospheric nitrogen acquired.

4. That there is a connection between root tubercles and the acquisition of nitrogen is clearly demonstrated. What this connection is, what are the relations of micro-organism to the root tubercles and to the acquisition of nitrogen, and in general how the nitrogen is obtained, are questions still to be solved.

5. The cereals with which experiments have been made have not manifested this power of acquiring nitrogen, nor do they have such tubercles as are formed on the roots of legumes.

6. In the experiments here reported the addition of soil infusions did not seem necessary for the production of root tubercles. A plausible supposition is that the micro-organisms or their spores were floating in the air and were deposited in the pots in which the plants grew.

7. In a number of these experiments, as in similar ones previously reported, there was a loss of nitrogen instead of gain. The loss occurred where there were no root tubercles; it was especially large with oat and corn plants, and largest where they had the most nitrogen at their disposal in the form of nitrates. This loss was probably due to the decomposition of the seeds and nitrates through the agency of micro-organisms.

8. The failure of earlier experiments to bring evidence of the acquisition of nitrogen from the air may very probably be due in part to this loss of nitrogen, but more especially to the precautions for excluding compounds of nitrogen, which precautions were calculated to likewise exclude the action of microbes, electricity or both, by aid, or at least in the presence, of which the nitrogen is assimilated.

In brief, the acquisition of large quantities of atmospheric nitrogen by leguminous plants which was demonstrated by the former experiments here and has been since confirmed by Hellriegel and others, is still further confirmed by the experiments herewith reported. These experiments in like manner confirm the observation by Hellriegel of the connection between root tubercles and the acquisition of nitrogen.

APPLICATION.

Farmers in all older portions of the country buy large quantities of nitrogen in artificial fertilizers. Nitrate of soda, sulphate of ammonia, dried blood, cotton-seed meal and fish scraps owe their fertilizing value mainly, and Peruvian guano and tankage largely, to nitrogen, and the same element is one of the chief ingredients of bone manures, ammoniated phosphates and many other fertilizers. According to an estimate by the Connecticut

Experiment Station, not less than $500,000 are expended annually for commercial fertilizers in Connecticut. A large amount of this goes for nitrogen, which is one of the dearest of the ingredients of fertilizers and costs at retail from eight or ten to eighteen cents or more a pound.

Nitrogen in Crops and Soil.—The quantities of nitrogen in ordinary crops and the cost of the same amount in the better commercial fertilizers are illustrated in the following table:

Amounts of Nitrogen in Ordinary Crops and Cost of Same Amounts in Commercial Fertilizers.

KIND OF CROP AND AMOUNT PER ACRE.	NITROGEN.	
	Pounds per Acre.	Cost at 15c. per lb.
Corn.—Grain, 50 bushels—2,800 pounds,	47.3	
Straw, 3,000 pounds,	25.4	
Total,	72.7	$10 91
Rye.—Grain, 20 bushels—1,120 pounds,	19.0	
Straw, 3,500 pounds,	19.4	
Total,	38.4	5 76
Oats.—Grain, 40 bushels—1,280 pounds,	23.3	
Straw, 2,000 pounds,	12.2	
Total,	35.5	5 33
Potatoes.—Tubers, 150 bushels—9,000 pounds,	31.5	4 73
Clover Hay.—Two tons—4,000 pounds,	80.3	12 05
Timothy Hay.—Two tons—4,000 pounds,	39.4	5 91

The plants must have this nitrogen or they cannot grow. They obtain part of it from the soil and the rest from the air. The nitrogen of the soil has either been accumulated in the past or is supplied in manures. A small quantity, in the form of ammonia and other compounds of nitrogen, is continually brought to the soil by rain or snow. Late research implies that soils acquire nitrogen from the air by the aid of microbes or electricity or probably both. The nitrogen in the soil is being continually leached away by drainage waters, and more or less of it escapes into the air. Soils which are not cultivated, and from which the produce is not removed, accumulate more nitrogen than they lose, so that many virgin soils have a large stock. By ordinary cultivation and cropping, the nitrogen is gradually exhausted, unless it is returned by manures or otherwise.

Of the total weight of the air, four-fifths is nitrogen. This means that over every square inch of the earth's surface there are twelve pounds of nitrogen, and over every acre of land, nearly 38,000 tons. Nearly all of the nitrogen of the air is in the form of what is called free nitrogen, that is, not combined with any other chemical element. A minute proportion is combined with other elements, in the forms of ammonia, nitric acid, etc.

The important question is: Can plants make use of atmospheric nitrogen to any considerable extent?

It has been agreed on all hands that the combined nitrogen of the air may be used by the plants; but the quantity is so extremely small as to be of comparatively little consequence. From the practical standpoint, it makes very little difference in what form the plants get the nitrogen, provided they can get enough.

If there are plants which can be used to gather any considerable amount of nitrogen from the air without cost, the fact is of immense importance, and ought to be clearly understood and rightly applied in practice. Interesting as this problem is to the farmer, it is none the less so to the chemist and vegetable physiologist, and has been the subject of active discussion and experiment for more than fifty years. There are certain kinds of plants, like clover, beans, and others belonging to the family of the legumes or papilionaceæ, which generally get on very well without nitrogenous fertilizers even in worn-out soils, and it would seem as though these plants, at any rate, must in some way be able to make use of the nitrogen of the air. But the classic experiments of Boussingault, in France, of Lawes and Gilbert, in England, and others, have been widely accepted as proving that plants cannot use the free nitrogen of the air and that they get practically very little combined nitrogen from the air, so that they are dependent upon that previously stored in the soil or supplied in manures.

The later investigations prove that plants acquire large quantities of atmospheric nitrogen and imply that the soil also appropriates it to greater or less extent. The legumes especially appear to have this faculty of gathering nitrogen from the air, and hence may properly be called "nitrogen collectors."

PRACTICAL INFERENCES.

The ability of legumes to gather nitrogen from the air helps to explain the usefulness of clover, alfalfa, peas, beans, vetches, cow-peas and allied plants as renovating crops, and enforces their importance for restoring fertility to exhausted soils. The judicious use of mineral fertilizers (phosphates, bone, potash salts, ashes, plaster, etc., containing phosphoric acid, sulphuric acid, potash and lime) will enable the farmer to grow crops of legumes as nitrogen collectors. These after being fed to his stock will, with proper care to collect and preserve all manure, both liquid and solid, enable him to return a "complete fertilizer" in the shape of barn-yard manure to his land. A further advantage of growing these crops is that the nitrogenous material, protein, which they contain in such great abundance, is especially valuable for fodder. They are of course highly valuable for green manuring when ploughed under.

IN CONCLUSION.

This subject has a wider significance than what has been said above implies. The future welfare of our race, material, intellectual, and moral, depends upon the food supply, or, in other words upon the product of the soil. This in turn reduces itself essentially to a question of phosphoric acid, potash, and nitrogen. Enough of the first two for indefinite time to come is assured in the deposits of phosphates and potash salts already discovered, but the probability of a sufficient supply of nitrogen has been questioned. This costliest of the fertilizing elements escapes from our soils into the air and into the sea, and is taken away by crops, and not completely returned. Artificial fertilizers promise to meet but a small fraction of the coming demand. If, as has been urged, the exhaustless stores of the atmosphere are not available to plants, the outlook is dark enough. But if the farmer may use his crops to gather it, without money and without price, we may dismiss our solicitude. With the assurance that plants obtain nitrogen from the air, the fear of starvation for the over-populated earth of the future may be ignored. That research will bring the brighter answer to this problem, there seems to be most excellent reason to believe.

TABLE 7.

Series XI., 1889. Champion of England Peas.

CONDENSED STATISTICS.

No. of Experiments.	Kilos of Sand.	Weight of Seed.	Nitrogen Supplied.			Soil Infusions.	Water Added During Growth.	Duration of Growth.	Root Tubercles at Harvest.	Mature Plants.							Nitrogen at End of Experiment.			Gain (or Loss—) of Nitrogen.
			In Seed.	In Nutritive Solutions.	Total.					Number.	Extremes of Hight.	Number of Pods.	Number of Peas.	Weight.			In Plants.	In Nutritive Solutions.	Total.	
														Vines and Fruit.	Roots (and Sand.)	Total.				
		Mg.	Mg.	Mg.	Mg.	Cc.	Cc.	Days			Inches			G.	G.	G.	Mg.	Mg.	Mg.	Mg.
151	3	1581	72.3	—	72.3	—	4200	78	None.	4	25–34	3	2	3.37	1.68	5.05	62.4	—	62.4	−9.9
152	3	1554	70.9	—	70.9	—	4300	78	None.	2	36–39	4	2	3.03	2.25	5.28	62.8	—	62.8	−8.1
153	3	1564	71.5	—	71.5	—	4400	79	Few.	4	32–40	3	3	2.69	1.26	3.95	58.0	—	58.0	−13.5
154	3	1553	71.0	—	71.0	50	4700	85	Fair Number.	4	36-46	6	8	5.72	2.45	8.17	145.8	—	145.8	74.8
155	3	1603	73.3	—	73.3	50	4800	85	Large Number.	4	44–50	5	8	5.99	2.74	8.73	151.9	—	151.9	78.7
156	3	1646	75.2	—	75.2	50	4700	85	Fair Number.	4	32–48	5	8	5.42	1.72	7.14	139.1	—	139.1	63.9
157	3	1543	70.7	151.8	222.5	—	7500	83	Fair Number.	4	44–51	8	14	12.47	7.96	20.43	282.7	—	282.7	60.2
158	3	1536	70.2	151.8	222.0	—	7600	85	Large Number.	4	54–62	10	16	14.52	3.84	18.36	343.8	3.8	347.6	125.6
159	3	1541	70.7	151.8	222.6	—	7800	85	Large Number.	4	48–64	9	18	14.38	4.67	19.05	340.0	2.0	342.0	119.4
160(1)	3	1552	70.9	151.8	222.7	50	8000	85	Large Number.	4	42–60	9	22	14.95	4.00	18.95	411.4	—	411.4	188.7
161	3	1588	72.6	151.8	224.3	50	7900	85	Few.	4	42–54	8	15	10.95	2.08	13.03	236.8	2.0	238.8	14.5
162	3	1643	75.0	151.8	226.8	50	8000	85	Large Number.	4	42–62	8	16	12.62	3.52	16.14	284.9	—	284.9	58.1
163	6	2405	109.9	447.7	557.6	—	12500	85	Few.	6	48–68	16	31	25.52	9.56	35.08	593.6	2.4	596.0	38.4
164(2)	6	2241	102.4	447.7	550.1	—	13000	85	Large Number.	6	48–68	18	30	27.67	10.75	38.42	672.7	20.5	693.2	143.1
165(3)	6	2300	105.1	447.7	552.8	50	13900	85	Large Number.	6	44–70	15	34	24.85	7.87	32.72	694.5	23.5	718.0	165.2
166(4)	6	2286	104.5	371.8	476.3	50	8900	54	Large Number.	6	42–64	—	—	17.27	6.67	23.94	618.2	105.5	723.7	247.4

(1) 8 peas eaten by birds. (2) 1 pea eaten by birds. (3) 3 peas eaten by birds. (4) Growth stopped when plant was in full bloom.

EXPLANATION OF TABLE.—In this series the plants in one group of six pots (No. 151–156) were grown without addition of nitrogen other than that in the seed. In six pots (No. 157–162) a small proportion, and in four pots (No. 163–166) a larger proportion of nitrogen was added in the form of nitrates. Half of the pots in each of these groups were treated with 50 cc. of pea soil infusion. In the column "Extremes of Hight" the hight of the shortest and the tallest plant in each pot is given. The weight of "Roots" and "Total" includes a small and varying amount of adhering sand, which it was not practicable to remove. When about half grown, some of the peas of the plants in Nos. 160, 164, and 165 were eaten by birds. No correction for the nitrogen thus lost is made, so the calculated gain in the last column is less than the actual gain. Ants attacked No. 166 when the plants were in blossom. The attempt to drive them out with a small quantity of borax was successful, but the plants were killed thereby.

TABLE 8.

Series VII., 1888. Champion of England Peas.

CONDENSED STATISTICS.

No. of Experiments.	Kilos of Sand.	Weight of Seed.	NITROGEN SUPPLIED.			Soil Infusions.	Water Added during Growth.	ROOT TUBERCLES AT HARVEST.	MATURE PLANTS.				NITROGEN AT END OF EXPERIMENT.			Gain (or Loss —) of Nitrogen.
										Weight.						
			In Seed.	In Nutritive Solutions.	Total.				Number.	Tops.	Roots (and Sand.)	Total.	In Plants.	In Nutritive Solutions.	Total.	
		Mg.	Mg.	Mg.	Mg.	Cc.	Cc.			G.	G.	G.	Mg.	Mg.	Mg.	Mg.
81	2.8	1111.5	48.9	—	48.9	—	700	None	3	2.26	1.06	3.32	41.9	—	41.9	−7.0
82	2.8	1048.5	46.1	—	46.1	—	600	Few.	3	1.03	2.07	3.10	44.4	—	44.4	−1.7
83	2.8	1059.0	46.6	—	46.6	25	900	Fair number.	3	2.78	2.55	5.33	132.2	—	132.2	85.6
84	2.8	1020.5	44.9	—	44.9	25	900	Large number.	3	2.64	1.79	4.43	161.6	—	161.6	116.7
86	2.8	1047.5	46.1	75.9	122.0	—	1000	Fair number.	3	2.55	5.75	8.30	138.1	24.8	162.9	40.9
87	2.8	979.9	43.1	75.9	119.0	25	1100	Few.	3	2.59	4.18	6.77	136.3	25.6	161.9	42.9
88	2.8	1054.0	46.4	75.9	122.3	25	800	Fair number.	3	2.30	1.81	4.11	124.6	24.2	148.8	26.5
89	2.8	1090.5	47.9	151.8	199.7	—	600	Few.	3	2.21	2.37	4.58	122.3	57.2	179.5	−20.2
91	2.8	1064.0	46.8	151.8	198.6	25	1100	Large number.	3	3.30	2.00	5.30	216.5	64.0	280.5	81.9
92	2.8	1030.0	45.3	151.8	197.1	25	1000	Large number.	3	2.93	1.31	4.24	183.6	69.4	253.0	55.9
93	6	1070.0	47.1	113.8	160.9	—	1300	None.	3	3.07	5.16	8.23	135.0	17.0	152.0	−8.9
94	6	1031.5	45.4	113.8	159.2	—	1700	Fair number.	3	2.56	1.20	3.76	122.8	28.2	151.0	−8.2
95	6	1063.5	46.8	113.8	160.6	25	1700	Large number.	3	2.31	1.27	3.58	131.6	38.1	169.7	9.1
96	6	969.5	42.7	113.8	156.5	25	900	Few.	3	.68	.84	1.52	44.7	95.0	139.7	−16.8

						Bacteria Cultures										
97	3	684.5	30.1	10.8	40.9	5	1800	None.	2	.98	2.06	3.04	37.1	—	37.1	-3.8
98	3	679.5	29.9	10.8	40.7	5	1900	None.	2	.90	.82	1.72	35.4	—	35.4	-5.3
99	3	627.0	27.6	10.8	38.4	5	1800	None.	2	.84	.56	1.40	22.8	—	22.8	-15.6
100	3	633.5	27.8	10.8	38.7	5	1800	None.	2	.54	.38	.92	23.7	—	23.7	-15.0
102	3	673.5	29.6	10.8	40.4	5	1700	None.	2	.70	.94	1.64	28.0	—	28.0	-12.3
103	3	620.0	27.3	86.6	113.9	5	1900	None.	2	1.38	.40	1.78	66.6	25.5	92.1	-21.8
104	3	673.5	29.6	86.6	116.3	5	1900	None.	2	1.97	1.18	3.15	83.7	2.2	85.9	-30.4
105	3	662.5	29.2	86.6	115.8	5	1800	None.	2	1.55	1.02	2.57	87.2	15.4	102.6	-13.2
106	3	668.5	29.4	86.6	116.1	5	1900	None.	2	2.36	2.47	4.81	97.6	—	97.6	-18.5
107	3	688.5	30.3	86.6	116.9	5	1700	None.	2	1.32	.47	1.79	64.8	8.6	73.4	-43.5
108	3	659.5	29.0	86.6	115.7	5	1700	Few.	2	2.05	2.62	4.67	97.5	—	97.5	-18.2

Explanation of Table.—The experiments of this series may be divided into three distinct groups. The pots of the first group (Nos. (81–92) held 2.82 kilograms of sand; those of the second (Nos. 93–96), 6 kilograms; and those of the third (Nos. 97–108), 3 kilograms of sand.

In the first group three experiments (Nos. 81–84) were without addition of nitrogen other than that in the seed; the plants in three others (Nos. 86–88) had a small amount of nitrogen, and those in the remaining three (Nos. 89–92) a larger proportion of nitrogen in the form of nitrates. The solution in which the plants of the second group (Nos. 93–96) were grown contained a small proportion of nitrogen as nitrates, though the larger amount of sand, and consequently of nutritive solution, made the actual amount of nitrogen added larger than in Nos. 86–88. In six experiments of the first group and two of the second 25 cc. of pea soil infusion, *i. e.*, infusions from a garden soil in which peas were growing, were added to each solution. In the experiments of the third group pure cultures of bacteria, from infusions of pea soil in a solution of peptone and beef extract, were added. The nitrogen contained in the culture medium when inoculated was 10.8 milligrams. Five of the pots (Nos. 97–102) were not treated with nitrates, and six (Nos. 103–108) received each 74.8 milligrams of nitrogen as nitrates in addition to that of the seed and the culture medium.

The weight of the roots is increased by a small amount of adhering sand.

TABLE 9.

Series X., 1889. East Hartford Early Peas.

CONDENSED STATISTICS.

No. of Experiment.	Kilos of Sand.	Weight of Seed.	NITROGEN SUPPLIED.			Soil Infusions.	Water Added during Growth.	Duration of Growth.	ROOT TUBERCLES AT HARVEST.	MATURE PLANTS.							NITROGEN AT END OF EXPERIMENT.			Gain (or Loss—) of Nitrogen.
														Weight.						
			In Seed.	In Nutritive Solutions.	Total.					Number.	Hight.	Number of Pods.	Number of Peas.	Vines and Fruit.	Roots (and Sand.)	Total.	In Plants.	In Nutritive Solutions.	Total.	
		Mg.	Mg.	Mg.	Mg.	Cc	Cc.	Days			Inches.			G.	G.	G.	Mg.	Mg.	Mg.	Mg.
115	1	511	20.4	—	20.4	–	1600	75	Large number.	2	15,	2	3	1.37	.67	2.04	33.0	—	33.0	12.6
116	1	486	19.4	—	19.4	–	1525	75	Few.	1	20,	1	2	.92	.22	1.14	25.4	—	25.4	6.0
117	¾	487	19.5	—	19.5	–	1575	80	Large number.	2	16, 32	2	5	1.66	.43	2.09	48.7	—	48.7	29.2
118	¾	483	19.3	—	19.3	40	1375	75	Few.	2	12, 16	2	2	.77	.25	1.02	23.8	—	23.8	4.5
119	1	526	21.0	—	21.0	40	1675	75	Large number.	2	18, 18	3	3	1.57	.51	2.08	52.5	—	52.5	31.5
120	1	480	19.2	—	19.2	40	1400	75	None.	1	15,	1	1	.41	.25	.66	11.5	—	11.5	-7.7
123	1	491	19.6	75.9	95.5	40	2150	75	Few.	2	24, 30	4	8	3.90	.55	4.45	100.2	—	100.2	4.7
124	1	486	19.4	75.9	95.3	40	2000	70	Few.	2	24, 27	3	9	3.73	.68	4.41	90.9	—	90.9	-4.4
125	1½	706	28.2	—	28.2	–	2250	75	Large number.	3	2, 12, 15	2	2	1.00	.65	1.65	30.7	—	30.7	2.5
126	1½	726	29.0	—	29.0	–	2350	75	Large number.	3	6, 15, 15	4	5	2.19	.74	2.93	69.5	—	69.5	40.4
127	1½	744	29.8	—	29.8	40	2350	75	Large number.	3	12, 12, 15	3	3	1.82	.65	2.47	56.3	—	56.3	26.5
128	1½	767	30.7	—	30.7	40	2150	70	Few.	3	12, 12, 12	3	3	1.45	.55	2.00	27.1	—	27.1	-3.6

129	1½	770	30.8	129.0	159.8	–	4900	84	Large number.	3	22, 27, 48	4	12	7.85	1.07	8.92	186.2	7.8	194.0	34.2
130	1½	758	30.3	129.0	159.3	–	5450	97	Fair number.	3	23, 54, 81	3	7	7.17	.94	8.11	153.2	18.7	171.9	12.6
131	1½	745	29.8	129.0	158.8	–	5900	99	Large number.	2	35, (27, 86)*	5	12	10.05	1.98	12.03	202.2	1.9	204.1	45.3
132	1½	788	31.5	75.9	107.4	40	3250	69	Few.	3	14, 21, 27	4	13	5.28	1.20	6.48	99.1	4.7	103.9	–3.6
133	1½	776	31.0	129.0	160.0	40	5600	97	Large number.	3	(9, 22)*, 30, 84	8	23	11.03	1.60	12.63	277.1	1.7	278.8	118.8
134	1½	710	28.4	75.9	104.3	40	3200	69	Few.	3	18, 24, 27	5	13	4.96	1.58	6.54	102.9	—	102.9	–1.4
135	3	998	39.9	—	39.9	–	6600	90	Large number.	4	14, 14, 30, 62	9	25	7.97	1.27	9.24	237.1	—	237.1	197.2
136	3½	940	37.6	—	37.6	–	7600	127	Large number.	4	14, 14, 14, 58	5	12	7.06	3.74	10.80	280.5	—	280.5	242.9
137	2½	958	38.3	—	38.3	–	3250	75	None.	3	10, 15, 15	1	1	.97	1.55	2.52	26.9	—	26.9	–11.4
138	3	1013	40.5	—	40.5	50	3350	75	Few.	4	12, 12, 15, 27	2	2	1.42	1.12	2.54	36.6	—	36.6	–3.9
139	3	970	38.8	—	38.8	50	5050	113	Fair number.	4	13, 15, 15, 44	4	6	2.81	.65	3.46	67.5	—	67.5	28.7
140	2½	981	39.2	—	39.2	50	3250	70	Fair number.	4	9, 12, 12, 12	4	4	1.57	1.20	2.77	36.8	—	36.8	–2.4
141	3	1006	40.2	113.8	154.1	–	7600	113	Fair number.	4	18, 24, 52, 54	6	16	8.53	3.31	11.84	154.6	2.1	156.8	2.7
142	3	1001	40.0	113.8	153.9	–	6000	83	Large number.	4	18, 22, 26, 72	9	25	11.62	2.17	13.79	273.2	—	273.2	119.3
143	3	1023	40.9	113.8	154.7	–	4700	75	Large number.	4	24, 27, 27	6	13	5.98	1.57	7.55	153.0	3.7	156.7	1.9
144	3	973	38.9	113.8	152.7	50	5000	75	Few.	3	22, 22, 22, 22	4	13	6.05	2.20	8.25	140.9	2.5	143.4	–9.3
145	2½	975	39.0	113.8	152.8	50	5800	83	Large number.	4	18, 30, 78	9	28	9.98	1.33	11.31	196.5	—	196.5	43.7
146	3	952	38.1	113.8	151.9	50	5700	83	Fair number.	3	10, 15, 30, 30	7	18	6.85	1.82	8.67	211.1	4.6	215.7	63.8
147	3½	1005	40.2	227.6	267.8	–	5600	70	Few.	4	21, 27, 27, 27	8	18	9.10	2.80	11.90	221.8	26.4	248.2	–19.6
148	3½	1046	41.8	227.6	269.4	–	10400	127	Large number.	4	30, 30,41,(102, 102)*	4	11	14.88	3.27	18.15	409.3	5.3	414.6	145.2
149	3½	1017	40.7	227.6	268.3	50	9100	99	Large number.	4	24, 33, 84, (18, 96)*	11	26	15.00	2.80	17.80	260.3	1.6	261.8	–6.5
150	3½	954	38.2	227.6	265.8	50	8200	97	Large number.	4	16, 35, 42, 83	11	24	12.40	3.60	16.00	319.1	32.9	352.0	87.2

*One of the plants had two branches of the hights given.

Explanation of Table.—This series includes three groups of experiments, Nos. 115–124, with ¾ or 1 kilogram of sand; Nos. 125–134, with 1½, and Nos. 135-150, with 2½, 3 or 3½ kilograms of sand. The plants of Nos. 115–120 were grown without addition of nitrogen other than in seed; three of them were with pea soil infusion and three without. The other two of the first group, Nos. 123 and 124, were treated with a small proportion of nitrogen as nitrates and with pea soil infusion. The next group was planned to include four experiments, Nos. 125–128, without nitrogen, and six, Nos. 129–134, with a relatively large proportion of nitrogen as nitrates. Half received pea soil infusion. Nos. 132 and 134, however, finished their growth (see column "Duration of growth") before the second addition of nitrates, and they consequently had a smaller proportion of nitrogen than the others of this group which had nitrates. In the third group, five, Nos. 141–146, had a small proportion of nitrates, and five, Nos. 136–140, had none. Nine of this group were treated with pea soil infusion.

TABLE 10.

Series VIII., 1888–9. Alfalfa.

CONDENSED STATISTICS.

No. of Experiment.	Kilos of Sand.	Weight of Seed.*	Nitrogen Supplied.				Soil Infusions.	Water Added During Growth.	Root Tubercles at Harvest.	Mature Plants.						Nitrogen at End of Experiment.			Gain of Nitrogen.
			In Seed.*	In Nutritive Solutions.		Total.				Number.	Branches.	Hight.	Weight.			In Plant.	In Nutritive Solutions.	Total.	
				1888.	1889.								Tops.	Roots (and Sand).	Total.				
		Mg.	Mg.	Mg.	Mg.	Mg.	Cc.	Cc.				Inches	G.	G.	G.	Mg.	Mg.	Mg.	Mg.
109	12	—	—	—	—	—	50	8700	Fair Number.	3	16	12–20	3.22	7.76	10.98	137.5	—	137.5	137.5
111	12	—	—	113.	227.6	340.6	—	8900	Few.	1	14	18	5.13	5.83	10.96	223.0	122.4	344.9	4.3
112	12	—	—	113.	227.6	340.6	—	11100	Few.	1	13	28	10.27	10.12	20.39	440.0	109.8	549,8	209.2
113	12	—	—	113.	227.6	340.6	50	12700	Large Number.	1	35	20	12.90	18.45	31.35	648.4	74.3	722.8	382.2
114	12	—	—	113.	227.6	340.6	50	9400	Few.	3	20	10–20	5.63	7.97	13.60	251.0	128.0	379.0	38.4

*The weights of the seeds and nitrogen supplied in them were very small and are omitted.

EXPLANATION OF TABLE.—In July, 1888, a number of experiments with alfalfa were started. The plants developed very slowly and at the approach of cold weather were housed for the winter, during which season they made practically no growth. In the spring of 1889 the sand in each pot in which the plants had survived was extracted with water, the nitrogen (in nitrates) determined and the difference between the amount of nitrogen thus found and that originally supplied in the nutritive solutions charged to the plants. The plants were transplanted into pots containing freshly purified sand and allowed to grow during the spring and summer. In pots Nos. 111–113 two plants each died. The nitrogen in the plants which died was not estimated, hence whatever nitrogen they may have taken from the nitrates supplied is counted as equivalent to so much lost. Only five experiments were carried to a successful completion, one without and four with the addition of nitrogen as nitrates. The plants of three of these experiments, Nos. 109, 113 and 114, were each treated with 25 cc. of an infusion of soil in which alfalfa had been growing luxuriantly and 25 cc. of pea soil infusion.

TABLE II.

Series XII., 1889. Oats.

CONDENSED STATISTICS.

No. of Experiment.	Kilos of Sand.	NITROGEN SUPPLIED.			Soil Infusions.	Water Added During Growth.	Duration of Growth*	ROOT TUBERCLES AT HARVEST.	MATURE PLANTS.						NITROGEN AT END OF EXPERIMENT.			Gain (or Loss—) of Nitrogen.
												Weight.						
		In Seed.	In Nutritive Solutions.	Total.					Number.	Hight.	No. of Oats.	Vines and Fruit.	Roots (and Sand).	Total.	In Plants.	In Nutritive Solutions.	Total.	
		Mg.	Mg.	Mg.	Cc.	Cc.	Days			Ft.		G.	G.	G.	Mg.	Mg.	Mg.	Mg.
167	6	4.1	—	4.1	—	4100	84	None on any of the Plants.	6	1	7	.75	.56	1.31	7.2	—	7.2	3.1
168	6	4.2	—	4.2	—	4100	84		6	1	7	.68	.58	1.26	5.8	—	5.8	1.6
169	6	4.3	—	4.3	50	4300	84		6	1	8	.72	.62	1.34	6.2	—	6.2	1.9
170	6	3.8	—	3.8	50	4100	84		6	1	6	.69	.56	1.25	6.5	—	6.5	2.7
171	6	4.2	303.5	307.7	—	7300	84		6	3	–	9.94	9.70	19.64	177.5	19.7	197.2	−111.5
172	6	4.3	303.5	307.8	—	8000	84		6	3	–	11.29	4.96	16.25	205.5	8.1	213.6	−94.2
173	6	4.3	303.5	307.8	50	8300	84		6	3	–	11.60	7.60	19.20	197.1	11.8	208.9	−98.9
174	6	4.3	303.5	307.8	50	8300	84		6	3	–	10.50	8.50	19.00	160.9†	9.1	170.0†	—
175	6	4.3	607.0	611.4	—	8600	84		6	3	–	15.80	6.10	21.90	391.7	25.7	417.4	−194.0
177	6	4.3	607.0	611.4	50	9500	84		6	3	–	14.08	10.60	24.68	396.8	40.2	437.0	−174.4
178	6	4.1	607.0	611.1	50	10600	84		6	3	–	13.62	10.19	23.81	332.2	23.8	356.0	−255.1

*The plants in No. 167-170 had done growing, but the others were a little past the "milk" when harvested.

†In determination of nitrogen in plants a portion estimated at one-fifth was lost. The results were sufficient to indicate that there had been considerable loss of nitrogen in the experiment and to imply that the actual quantity of nitrogen in the plants was about the same as that of the others (No. 171-173) of this group.

EXPLANATION OF TABLE.—In Experiments Nos. 167-170, no nitrogen was added other than that contained in the seeds. Nos. 171-174 received a small proportion and Nos. 175-178, a larger proportion of nitrogen as nitrates. In each of six cases 50 cc. of pea soil infusion were added.

TABLE 12.

Series IX., 1888. Corn.

CONDENSED STATISTICS.

No. of Experiment.	Kilos of Sand.	Weight of Seed.	NITROGEN SUPPLIED.			Soil Infusions.	Water Added During Growth.	ROOT TUBERCLES AT HARVEST.	MATURE PLANTS.				NITROGEN AT END OF EXPERIMENT.			Gain (or Loss—) of Nitrogen.
			In Seed.	In Nutritive Solutions.	Total.				Number.	Weight.			In Plant.	In Nutritive Solutions.	Total.	
										Tops.	Roots (and Sand).	Total.				
		Mg.	Mg.	Mg.	Mg.	Cc.	Cc.			G.	G.	G.	Mg.	Mg.	Mg.	Mg.
48	9	929.5	17.9	—	17.9	—	5900	None on any of the Plants.	2	2.132	5.287	7.419	21.6	—	21.6	3.7
49	9	941.7	18.1	—	18.1	—	5900		1	.176	1.478	1.654	6.7	—	6.7	-11.4
25	16	942.0	18.1	—	18.1	25	11300		2	5.093	8.028	13.121	38.1	—	38.1	20.0
36	16	969.9	18.6	—	18.6	25	10900		2	4.272	11.050	15.322	38.7	—	38.7	20.1
26	16	979.5	18.8	113.8	132.6	—	12700		2	21.490	26.800	48.290	170.5	—	170.5	37.9
27	16	966.2	18.6	113.8	132.4	—	12200		2	23.960	27.890	51.850	154.5	—	154.5	22.1
34	15	975.9	18.7	113.8	132.5	25	11800		2	21.730	16.220	37.950	135.6	—	135.6	3.1
35	15	974.1	18.7	113.8	132.5	25	12100		2	21.260	18.790	40.050	130.8	—	130.8	-1.7

EXPLANATION OF TABLE.—In the last four experiments a small proportion of nitrogen, in the first four none, in the form of nitrates was added. In one-half the cases 25 cc. of an infusion from the soil in which corn was growing were added in each case. In all of the experiments the quantity of food supplied to the plants was insufficient for the normal growth.

TABLE 13.—*Series XIII., 1889. Corn.*

CONDENSED STATISTICS.

No. of Experiments.	Kilos of Sand.	Weight of Seed.	Nitrogen Supplied.			Soil Infusions.	Water Added During Growth.	Duration of Growth.	Root Tubercles at Harvest.	Mature Plants.						Nitrogen at End of Experiment.			Gain (or Loss–) of Nitrogen.
											Hight.		Weight.						
			In Seed.	In Nutritive Solutions.	Total.					Number.	Stem.	Greatest.	Tops.	Roots (and Sand).	Total.	In Plants.	In Nutritive Solutions.	Total.	
		Mg.	Mg.	Mg.	Mg.	Cc.	Cc.	Days.			Inches.	Inches.	G.	G.	G.	Mg.	Mg.	Mg.	Mg.
179	9	1150	21.1	—	21.1	—	4800	106	None on any of the Plants.	2	10, 8	20, 23	3.60	5.55	9.15	31.2	—	31.2	10.1
180	12	1114	20.4	—	20.4	—	5000	107		2	5, 9	18, 28	4.85	4.60	9.45	35.8	—	35.8	15.4
181	12	1183	21.6	—	21.6	—	5000	107		2	7, 8	16, 24	3.55	3.35	6.90	27.6	—	27.6	6.0
182	12	1186	21.7	—	21.7	50	5000	107		2	7, 8	22, 22	3.60	3.80	7.40	31.5	—	31.5	9.8
183	12	1114	20.4	—	20.4	50	4900	106		2	8, 8	24, 28	4.20	3.15	7.35	32.7	—	32.7	10.3
184	12	1106	20.3	—	20.3	50	4900	106		2	10, 6	25, 22	2.85	2.60	5.45	25.8	—	25.8	5.5
185	11	578	11.6	417.3	428.9	—	8700	127		1	45	56	22.85	13.42	36.27	323.9	—	323.9	–105.0
186	16	1081	19.8	607.0	626.8	—	13500	127		2	57, 34	57, 43	48.85	12.27	61.12	509.1	4.1	513.3	–113.5
187	17	1098	20.1	607.0	627.1	—	13200	127		2	52, 57	52, 60	42.33	15.88	58.21	486.9	—	486.9	–140.2
188	17	1146	21.0	607.0	628.0	50	12600	127		2	52, 50	52, 60	51.72	17.51	69.23	535.3	—	535.3	–92.7
189	17	1126	20.7	607.0	627.7	50	13700	127		2	54, 49	54, 49	54.90	14.80	69.70	534.0	14.9	544.9	–78.8
190	17	1159	21.2	607.0	628.2	50	14100	127		2	46, 26	52, 43	50.07	18.93	69.00	569.9	—	569.9	–58.3
191	22	1111	20.4	1631.4	1651.8	—	16900	127		2	60, 79	64, 79	94.00	20.35	114.35	1213.7	106.8	1320.5	–331.3
192	22	1174	21.5	1517.6	1539.1	—	16600	127		2	58, 63	58, 63	78.42	21.35	99.77	1185.2	79.9	1265.1	–274.0
193	29	1179	21.6	1517.6	1539.2	—	21900	127		2	64, 66	64, 66	89.03	34.82	123.85	1340.7	4.8	1345.5	–193.7
194	22	1138	20.8	1517.6	1538.4	50	18400	127		2	61, 49	61, 59	74.33	21.80	96.13	1300.8	10.4	1311.2	–227.2
195	22	1081	18.5	1517.6	1536.1	50	18300	127		2	66, 50	60, 50	67.04	29.14	96.18	1367.2	—	1367.2	–168.9
196	30	1114	20.4	1517.6	1538.0	50	21900	127		2	46, 58	46, 58	75.30	37.85	113.15	1312.3	—	1312.3	–225.7

EXPLANATION OF TABLE.—In Nos. 179–184 no nitrates were supplied; in Nos. 185–190 a small proportion; and in Nos. 191–196 a large proportion of nitrogen was added in the form of nitrates. To one half of the experiments of each group 50 cc. of an infusion of a soil in which corn was growing were added. Under "Hight," the length of the plant from soil to top of tassel is stated as hight of stem; the greatest hight was found by measuring from soil to extremity of longest leaf. Analyses of the residual solutions, from time to time, implied that none of the plants had received enough food for normal growth.

BACTERIA IN MILK, CREAM AND BUTTER.

By H. W. Conn, Ph. D.

During the past year and a half investigations on the bacteria of milk have been conducted, in behalf of the Station, by H. W. Conn, Professor of Biology in Wesleyan University. The following is a summary of some of the more interesting results of the work, which is being continued:

The term *bacterium*, plural *bacteria*, is used to comprise a class of organisms found abundantly in air, water, soil, and in plants and animals. As commonly used the term includes a large number of organisms which the naturalist divides into three classes. bacteria, yeasts and moulds. In a strict scientific sense the word bacteria should include only a class of micro-organisms which multiply by transverse division (fission). Popularly, however, it is used to include also yeasts, which are distinguished from bacteria by having a different method of multiplication. The word *microbe* has been recently introduced as a substitute for this popular use of the word bacteria. In the present paper the word is used in its broader and collective sense.

Bacteria are found in immense numbers everywhere, and they play an important part in nature. They are all microscopic and very simple in structure. Commonly they are not more than 1-3000 of an inch in length. In shape they show three chief varieties, which may be compared to a lead pencil (bacillus), a ball (cuccus), and a corkscrew (spirilum). So simple are they that the highest powers of microscope are inadequate to make out any definite internal structure, and with the best optical appliances they appear as scarcely more than simple dots and rods. From their general method of growth it is concluded that they should be classed with plants rather than animals, in spite of the fact that many of them are endowed with motion. They multiply with the greatest rapidity—a single individual in the course of a few days being able to give rise to millions. While they are thus growing and multiplying they produce great changes in the medium in which they grow. All fermentation, such as raising of bread, fermenting of beer, cider, etc., putrefaction and decay, such as rotting of potatoes, decay of wood, etc., are produced by the organisms here included. They are of immense value as well as injury. Through their agency dead animal and vegetable matter is decomposed and prepared to be incorporated with the soil and to be used as food by plants. It is doubtful if vegetable life could be long continued without their aid. On the other hand they are the cause of much trouble, many of the most dangerous diseases, cholera, scarlet fever, typhoid fever, consumption, bovine tuberculosis, hog cholera, chicken cholera, etc., being produced by the growth of microscopic organisms in the body. It must not be understood that it is the same kind of bacteria that produce the beneficial and injurious effects. Although bacteria are very small, there are different species just as distinct as those of larger plants and animals. The disease germs are mostly parasites upon the animal body and many of them are unable to live elsewhere. We have learned to distinguish one class of bacteria which produces diseases in the animal body and we call them *pathogenic bacteria.* Besides these there is an immense number of bacteria living free in the air, water and soil, and producing many processes in nature entirely independent of any injury to animals. These are the *non pathogenic bacteria.* It is with the latter that we are concerned in the present paper.

METHODS OF EXPERIMENT.

The object of the experiments upon which this paper is based is to determine as far as possible the relation of bacteria to normal dairy processes. It is evident that bacteria must be of considerable importance to the milkman and the makers of butter and cheese, and it is our purpose to determine what effects the *common* bacteria have upon milk and what part they play in butter and cheese making. For this reason our experiments have been chiefly confined to the ordinary saprophytic bacteria which are normally found in milk, and various normal products of milk have served as the starting point for work. The methods of the experiments have been those common in modern bacteriological research. As a culture medium the ordinary beef-peptone solution, stiffened with 12 % gelatine or 1 % agar-agar, has been used in all cases. The agar-agar was employed in studying species which liquify gelatine, and it was found more convenient for use in warm weather on account of its higher melting point. Various milk products have furnished us with plenty of bacteriological material, sweet milk, sour milk and ripened cream having thus far occupied most of our attention, although some work has been done upon butter and cheese. The milk which we have used has been obtained from several different sources, including a number of dairies. Cream has also been obtained from several sources, some of the specimens having been ripened before being sent to us, some being examined while still sweet, and some being ripened in the laboratory. A drop of the milk or cream has been transferred by a sterilized platinum needle to a gelatine or agar tube, and an ordinary plate culture is made. After two or three days' growth the plates have been carefully studied and specimens of all the colonies which appeared different fished out and inoculated into gelatine culture tubes for future study. The cultures thus made have been subsequently purified by successive replatings until uniformity of results gave assurance that the cultures were pure. In order to place complete reliance upon the results, this replating has been repeated six times and no experiment has been relied upon until repeated several times with uniform results.

In this way a large number of yeasts, bacteria and moulds were soon obtained. Since milk is an excellent medium for the growth of bacteria it is evident that specimens which have been exposed to the air for any length of time will be likely to be contaminated by almost any of the species of bacteria which may be present in the air. For this reason the number of species found in the milk products soon proved so great that it became impossible to study them all at the outset. After a large number of preliminary experiments some fifteen species were selected for most careful study. In the selection of this number care was taken to include as great a variety as possible, and the fifteen species studied comprised those which were shown by the preliminary experiments to produce a wide variety in their effects upon milk. These species were cultivated in gelatine, on potato, in boullion and on gelatine plates, and were microscopically studied until their characters were well determined. In addition to the species thus isolated from milk we have used nine species of bacteria kindly sent by Prof. Sedgwick of the Massachusetts Institute of Technology, which he had isolated from sewage water. We have also received from Dr. Booker of Baltimore pure cultures of fifteen species obtained by him from the intestines of nursing children.

Having thus obtained pure cultures, we have next endeavored to name the species from bacteriological literature. The indefiniteness of the characters which are usually given to describe species, especially the saprophytic forms, has rendered this very difficult. As would naturally be expected a majority of the species found do not agree with any described elsewhere and are probably new species. Many common species known to bacteriologists have, however, been found among the species isolated. *Bacillus subtilis*, *B. acidi lactici*, *B. flourescens liquifaciens* (several varieties), *B. flourescens putidus*, *B. figurans*, *Tarula rosaceous and Oidium lactis* are among the common species.

A few quantitive estimations of the number of bacteria in milk have been made. These have, of course, very little significance since the number will depend so largely upon the length of time since the milk has been drawn from the cow and the temperature at which it has been kept. In making quantitive determinations one-tenth of a cc. of milk has been measured as closely as possible in a finely graduated pipette and dropped into a tube of melted culture fluid. A plate is made from it and the colonies counted after two or three days' growth. Such a method is, of course, very rough, owing to the difficulty of measuring accurately such a small amount of milk, but when it is seen that the number of bacteria range from 300 to 6,000,000 per cc., according to the condition of the milk, it is evident that accurate estimations would not be worth the time it would take to make them.

In determining the effect of the various bacteria upon milk we have used test tube inoculations in most cases. The milk has been sterilized by discontinuous heating. In a few instances this has been done by heating to about 70° C. for ten minutes upon six successive days, but this being a long process it has been found more convenient to place the milk in the steam sterilizer. Steaming for twenty minutes upon three consecutive days is always sufficient to sterilize milk, and it will subsequently remain sweet indefinitely. The milk sometimes turns slightly brown from the caramelization of the sugar, but this does not interfere with the growth of bacteria. Milk thus sterilized serves perfectly well in testing the effects of the various species of organisms, though they do not grow so well in it as they do in unboiled milk. These specimens of sterilized milk have been inoculated with the pure cultures of bacteria. After the inoculation the milk has been left for about two weeks at the ordinary changing temperature of the room (about 20° C.). If no effect has been produced at this temperature it is transferred to a warm oven with a temperature of about 35° C. Here the cultures have been left until the complete action of the bacteria upon milk had taken place. No experiments have been made to determine the effect of different temperatures with any more exactness than indicated by these experiments. In studying the effect of the different bacteria upon milk we have tried to determine as many details as possible. Their power of coagulating the milk, the character of the curd when formed, the production of an acid or alkaline reaction, the relative amount of whey, the power of the bacteria to dissolve the curd by digesting it and producing peptones, the colors produced, the odors which become prominent after the organisms have acted for a time, and any other special character which the different species may show. No extended work has yet been possible upon the chemical nature of the decomposition products.

Accompanying the experiments upon milk, four other series of test cultures have been made. Each of the organisms studied has been grown in four different culture media. *a.* A beef boullion made by soaking beef in water for twenty-four hours, and subsequently straining and filtering. *b.* The ordinary beef peptone culture fluid without gelatine. *c.* Beef peptone culture fluid to which has been added 3 % of milk sugar. *d.* Beef peptone culture fluid to which has been added 3 % of glucose. All of these solutions were carefully neutralized with carbonate of soda before inoculation, and the subsequent effect of the growth of bacteria carefully noted. These experiments assist in determining the power of the various organisms in producing acids by breaking up sugars, and are very instructive when compared with the effects of the same organisms upon milk.

The work already done along these lines comprises many hundreds of cultures. An account of the details of these experiments in order to be of any value would require many pages of description of species, as well as of their effects upon milk and the various culture media. Inasmuch as the experiments are still in progress and bid fair to continue for some time longer, it is thought best to reserve their detailed account until a later date. The present paper is designed to give only a brief summary of the important facts concerning the relation of bacteria to milk and its products, and they are, therefore, only sketched in outline. For this reason also the paper includes the results of other investigators as well as the general results of our own experiments.

BACTERIA IN MILK, CREAM, AND BUTTER.

Milk is a medium in which bacteria grow with the greatest readiness. Our experiments have thus far given indication of some thirty or forty species of bacteria that are floating in the air in this vicinity, every one of which is found in cream, and grows with the greatest facility in milk. Probably none of those which we have studied produce disease, and hence are called non-pathogenic. The researches of others have shown that many of the disease (pathogenic) germs will also grow readily in milk. Cream is also a good medium for their growth. We have usually found a larger variety of bacteria in the specimens of cream studied than in milk. This seems to be due to the fact that the cream will keep a longer time without putrefying and will thus allow some of the slower growing species of bacteria to get a chance to develop sufficiently to become appreciable. Butter does not seem to be a good medium for their growth. This is probably due chiefly to the presence of the salt commonly added to the butter which has the power of hindering the bacteria growth. Perhaps it is also partly due to the fact that good butter, being mostly fat, contains only a small amount of albuminous matter, which the bacteria need as food. We have always found bacteria present even in the sweetest butter. The common souring and curdling of milk are caused by the growth of bacteria.

If milk or cream be kept free from them the ordinary fermenting changes do not take place. It has been shown by several observers that by using sufficient precautions, it is possible to draw milk from the cow in such a way as to prevent it from becoming contaminated with bacteria, and then if it is immediately received in absolutely clean (sterilized) vessels, and if further access of bacteria to the milk is prevented, the milk will keep sweet and good indefinitely. It is certain that such milk will not undergo any of the ordinary fermentative changes, though recent experiments have indicated that some spontaneous changes do occur in it shortly after being drawn, somewhat analogous to the clotting of the blood. These spontaneous changes are commonly, however, very slight, and indeed ordinarily inappreciable, though they may be of considerable importance in the subsequent handling of the milk and cream.

Milk and cream under ordinary conditions cannot be kept free from bacteria. Milk drawn from a healthy cow is free from them, but they may get into it from the hands of the milker, or the cows' tails, or when the milk is in contact with the air during milking. A single experiment will indicate the difficulty of keeping them out of milk. Eight test tubes were washed perfectly clean and plugged with a mass of cotton. They were then heated very hot until all living matter in them was killed. These were taken into a milking yard, the cotton plug was taken out and milk drawn directly from the cow into the tubes, and the cotton plug replaced. Of these eight tubes, seven soured in a few days and many bacteria were found in them. The other remained sweet for a long time, but eventually it also changed. From this experiment it is seen that in the few seconds in which it was exposed to the air the milk was contaminated with bacteria. A very common source of contamination of milk is from vessels in which the milk is placed. These, unless recently washed in boiling water, contain bacteria clinging to their walls. These bacteria begin to grow as soon as the milk gets into the vessels, and in a few hours will multiply so as to be extremely abundant.

Although it is thus a matter of extreme difficulty to obtain milk from the cow in such a manner as to prevent it from becoming contaminated by bacteria, it is not difficult to destroy them after they have succeeded in getting into the milk. All of the bacteria may be readily killed by heating them to a boiling temperature for ten minutes upon three successive days. Milk thus deprived of bacteria by heating is said to be sterilized, and if we now prevent the further entrance of bacteria by closing with a cotton plug the vessels in which the milk has been sterilized, it will remain sweet indefinitely. By thus sterilizing a lot of milk and then putting into it a few of any particular species of bacteria (*i. e.* inoculating them), we can easily determine the effect which this species produces upon the milk independently of all others. It is in this way that our experiments have been made.

NUMBER OF BACTERIA IN MILK. DIFFERENT SPECIES.

The number of bacteria in milk will depend chiefly on three things: 1. The cleanliness of the vessels. 2. The temperature of the milk, warmth being favorable to their growth. 3. The length of time that the milk has been standing. Ordinarily the number of bacteria in the air is of comparatively little importance, unclean vessels being the great source of contamination. If, however, the milk vessels should be perfectly clean, which practically never happens in ordinary dairy practice, the number of bacteria in the air becomes a more important factor. In the case of cream which commonly stands exposed to the air for a longer time, the bacteria of the air are of more importance than they are in milk. The number of bacteria present in milk varies widely and depends chiefly upon the length of time the milk has been standing and upon the temperature. Estimates made upon milk kept under different conditions have shown numbers ranging from 300 to 6,000,000 per cc. (in round numbers from 300,000,000 to 6,000,000,000 per quart). The effect of temperature is well shown by the following experiment: Some milk which had been standing in a cool place for three days was examined and found to have about 10,000 bacteria per cc. (10,000,000 per quart). The milk was then allowed to stand in a warm room for seven hours and during this time the bacteria increased to 1,000,000 per cc., thus multiplying 100 fold in seven hours. From this it will appear that the most effective method of preventing milk from souring is to keep it cool, and we find here an explanation of a common experience of milkmen who frequently find that night's milk, which has been cooled in water during the night, will remain sweet longer than morning's milk, which is taken for delivery directly from the milking yard without cooling. The milk when drawn from the cow is at a temperature best adapted to bacteria growth, while the cooled milk must first be warmed by the air before bacteria growth can take place with much rapidity. Thus the bacteria in the morning's milk will grow while the previous night's milk is becoming warmed by the air and thus will actually get several hours the start of those in the night's milk, and the morning's milk will therefore be the first to sour. It is, therefore, evident that the immediate cooling of the milk is of great assistance in preventing its souring even if the milk is subsequently warmed again.

The number of bacteria in ripened cream is beyond comprehension. In specimens of cream which has ripened for two or three days as many as 100,000 bacteria have been found in a single drop. Even under conditions most unfavorable to their growth, in a cool cellar during the winter, 12,000 have been found in a single drop. Each of these is capable of multiplying with the greatest rapidity, producing incalculable numbers in the course of a few days.

Not only is the number of individual bacteria found in milk very great, but the number of different species is considerable.

As would naturally be expected, we have found that the number of species is greater in milk that has been kept for some time than in comparatively fresh milk. If the milk is examined when sweet or just beginning to sour, but before it curdles, there is ordinarily not a very great variety of species present. If it is allowed to curdle and stand for some days in the air the variety of micro-organisms is much increased. In our experiments we have isolated over forty different species of micro-organisms from milk or cream. No single specimen of milk or cream contains them all nor are all of the species equally abundant or equally constant. Some are almost always found, and others only occasionally. All of these species have been found in normal milk and cream and may consequently be regarded as likely to appear in milk under ordinary conditions.

The number of bacteria present has, however, no significance until we know something of their effect. Some are harmless, some are hurtful; some affect cream, milk, and butter injuriously, and others do not. The effect produced by most of these organisms upon milk is striking.

Among the large number of species of organisms thus found in milk there are two or three that are so constant as to be fairly called characteristic of milk. In calling them characteristic it is not meant, of course, that they belong naturally to *milk*, for, as we have seen, normal milk contains no bacteria when drawn from the cow. These few characteristic species would seem to be the most common species around dairies and therefore they most commonly get into milk: 1. The first is the organism which causes the common souring of milk during hot weather (*Bacillus acidi lactici*). This species upon being introduced into milk will grow rapidly and soon decompose it. The milk sugar present is broken up into lactic acid and carbonic dioxide, and the other ingredients of milk give rise to other decomposition products which are not yet fully determined. The acid thus formed produces the sour taste and at the same time curdles the milk by hardening or coagulating its casein. Other decomposition products cause it to acquire its well known taste and odor. This organism is very abundant in the air during warm weather, but in the winter it is much less abundant. Indeed, we have not yet been able to determine its presence in any of the specimens of milk yet examined during cold weather. 2. A second common species of organism is *Oidium lactis*, which is almost constantly found in sour milk.

It gives rise to certain decomposition processes in milk, but does not seem to be of much importance in the dairy, since its growth is comparatively slow. 3. There are always found in ordinary dairy milk bacteria which produce a bitter taste if they are allowed to grow unhindered. There seem to be two or three species which have this effect.

ACTION OF DIFFERENT KINDS OF BACTERIA IN MILK.

As concerns their action, we may divide them into three classes: 1. Some species of bacteria have no visible effect upon the milk. The milk in which they are growing does not become acid nor alkaline, nor does it curdle. There are, however, produced certain odors which show that the bacteria are really causing decomposition of the milk. 2. Some species produce a certain amount of acid (lactic or acetic acid) from the decomposition of milk sugar. The acid produced may be sufficient to curdle the milk or it may be insufficient for this. Some of these species will curdle the milk at a warm temperature (90° F.), while they will not do so at a cool temperature (60° F.). These would accordingly curdle the milk in the summer but would not do so in the winter, or at least less readily. 3. Some species of bacteria curdle the milk but produce no acid, the milk sometimes even becoming alkaline instead. In these cases the curdling is probably produced by a ferment somewhat like the ferment of rennet.* It is very important to notice that most of this last class of bacteria after having curdled the milk begin by their further growth to dissolve the curd causing it to go through changes similar to those of digestion. After two or three weeks the curd may be completely dissolved into a transparent liquid containing peptones.

Although, as thus indicated, the various species of bacteria may be grouped into three classes as concerns their effect upon milk, we find that each species has its own definite action in matter of details. The curdling is very different in character with different species. In some cases a hard curd and a clear liquid are formed; in others a curd is formed, but no liquid is separated from it; in still other cases the whole milk is turned into a semi-gelatinous mass. Sometimes the curd is easily broken or cracked like the curd of common milk; in other cases it is very tenacious, sticky, and slimy. Sometimes the curd is dissolved in a few days and the milk is left as a clear and almost transparent liquid. It is found also that there arises, as the result of the decomposition of the milk, odors which are frequently characteristic of the different species of bacteria. Among the odors which have been noticed there are the following: the odor of sour milk, sour cream, rancid butter, fresh cheese curd, musty cheese, sour dough, the odor produced in bread dough which is acted upon by yeast, various odors of putrefaction and decay, and others which cannot be described because of the lack of words in our language to distinguish odors.

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* The curdling of milk produced by rennet is not due to the action of bacteria.

In short, the effect of each species of bacteria seems to be different in some respects from the others. In many of the cases the dairyman or the housewife would say that the milk had soured, but careful study shows that what is called sour milk may be quite varied in character.

BACTERIA IN CREAM.

Our experiments were undertaken in the expectation that the so-called "ripening" of cream would prove to be a definite change due to the growth of bacteria. Having found that the souring of milk is less simple than had been supposed, we are prepared to find that the "ripening" of cream is also a complex process. It is not easy to say just what is meant by "ripened" cream. In ordinary farm practice cream is usually allowed to stand for a few days before churning, when it becomes somewhat thickened and acquires a pleasantly sour odor. In our creameries the cream is also ripened, though for a shorter time, and it does not become so thick or so sour. That the ripening is due to the growth of bacteria there can be no doubt. Ripened cream always contains these organisms in almost inconceivable abundance. In some places the ripening is hastened by adding a little sour cream as a "starter." This simply means the addition of a large number of bacteria, which of course hastens the process. Sometimes an artificial starter in the form of an acid is added. This practice proceeds upon the supposition that the ripening is due to the formation of an acid, which is probably a secondary matter. It is doubtful if this kind of a starter has any definite value.

By successive heatings, specimens of cream have been deprived of all bacteria, and it is then found that the cream remains unchanged indefinitely. In these specimens of sterilized cream we have planted the various species of bacteria that we have experimented upon. All of them grow well in the cream, but no one of them has been found to produce exactly what we feel justified in calling ripened cream. Some curdle it; some cause it to putrefy. From all of our experiments we conclude that the ripening of cream is a complex matter. The souring is apparently due to a process similar to the souring of milk: the thickening in part to the curdling of the small amount of casein left with the cream, and in part to immense numbers of bacteria that develop. Another important factor in the ripening of cream is the decomposition of the albuminous matter present. In general we infer that different kinds of bacteria assist in the ripening of cream, but doubt whether any one has such a definite relation to it as the sour-milk bacterium has to the curdling of milk.

OBJECTS OF RIPENING CREAM.

There seem to be three chief objects in ripening cream: 1. It is a matter of experience that the butter will separate more readily from ripened cream than it will from sweet cream. The churning is thus made easier and there will be more butter obtained from a given quantity of cream. 2. Some think that the butter will keep longer when made from ripened cream. 3. Butter made from ripened cream has a better flavor than that made from sweet cream, the latter tasting "flat." A simple explanation of these three facts is suggested, if not warranted, by the facts at hand, and may be of interest to butter makers. It is a well known fact that cream contains, besides the fat and casein, a certain quantity of albuminous matter. It is quite definitely ascertained that this albumen holds some close relation to the fat. It has been formerly believed that it forms an envelope around the fat globules and that the object of the churning is to shake the globules free from these envelopes. This view is to-day not very commonly accepted. Recently Dr. Babcock, of the Wisconsin Agricultural Experiment Station, has pointed out * that shortly after milk is drawn from the cow there appears in it a fine, inappreciable network of fibers, which produce in the milk a slight thickening somewhat like the clotting of blood, except that it is much less marked. This, which Babcock calls "fibrin," is of an albuminous nature and will readily putrefy. When the cream rises to the surface of the milk, a considerable quantity of

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*Agr. Exp. Sta. of Wis., Bull. No. 18.

this so-called fibrin is entangled with it and is skimmed off with the cream. The butter globules are so entangled in this network of fibrin that they must be shaken by churning until they are set free.

Without necessarily accepting in full either of these views, we certainly cannot be far out of the way in assuming that in some way the fat globules are in close connection with the albumen, and that the object of the churning process is to shake them free, so that the free fat may unite to form the butter granules. Now, in the time that the cream is ripening the numerous bacteria are at work upon this albuminous matter, feeding upon it and decomposing it. The breaking down of the albuminous matter is also assisted by the acid that is formed by the bacteria, for it is a well-known fact that acid will greatly assist in the solution of albuminous materials. After the albumen is thus partly dissolved by the action of the bacteria and the acid, the butter globules will much more readily be shaken free from them, the churning be made easier, and more butter will therefore be obtained.

The superior keeping property of butter made from ripened cream is a matter of comparatively little importance. Indeed, it is not certain that such butter has really any superior keeping powers. There is no doubt that bacteria are the cause of rancidity in butter. Bacteria cannot live upon pure fat, but require for food a certain amount of albuminous matter. It follows that the more albuminous matter there is in the butter, the more readily will they grow and the quicker will the butter become bad. If the cream is churned before the albuminous matter has become decomposed, the butter will usually contain more of it than will butter made from cream after the albuminous matter has decomposed. Butter made from ripened cream will naturally contain more bacteria than that made from sweet, since the ripened cream itself contains them, but this is a matter of less importance than the ability of the bacteria to grow and multiply in the butter, and for reasons above stated this they can more readily do in butter made from sweet cream.

From this it would seem that the value of ripening cream depends upon the albuminous matters that are present in the cream, and any process that diminishes them diminishes the necessity of ripening, at least so far as concerns the two objects above mentioned. Babcock has shown that the quicker the cream rises the less will be the amount of the fibrin entangled with it, and that when cream is separated by a centrifugal machine, a considerable part of the albuminous matter collects on the drum of the machine and less in the cream. It would seem, therefore, that there would be less need of ripening centrifugal cream than that raised in the more common way.

A third object attained by ripening cream is to give a certain flavor to the butter which is not obtained in butter made from sweet cream. This is a matter of as much importance to butter makers as either of the other two, for the value of butter usually depends more upon its taste than upon its keeping properties. The flavor of butter is due not to the butter fat but to certain volatile products present in small quantities. Now the odors produced by the growth of the various bacteria in milk plainly indicate that volatile substances are being produced during the ripening of the cream as the result of the decomposition. It is impossible to notice the odors produced by the growth of the different species of bacteria without being convinced that they have something to do with the superior flavor of the butter made from ripened cream. But the relation of the flavor of butter to the ripening of cream, to the handling of the butter, and to the food of the cows, is a matter too vague and indefinite to warrant at present any positive statements.

CLEANLINESS IN DAIRYING.

It must be remembered that many bacteria are so minute that thousands of them might occupy less space than the point of a needle; that they multiply so rapidly that millions may be produced in a short time from a single one; that organic (animal and vegetable) matters, including many forms of what are ordinarily called dirt, are media for them to grow in; that milk is especially adapted to their development, and the most minute quantities of it may serve for their dwelling place and furnish food for their rapid growth; and that they are sure to adhere to the surface or cling in the joints of vessels that have contained milk. Bearing all of these facts in mind, the necessity for thorough cleansing of all vessels used in handling milk is apparent. To wash such vessels so that no particles of dirt will remain on the surface or in the joints is extremely difficult. It has been frequently demonstrated that no amount of washing in cold or even warm water will remove all bacteria. It is necessary to use *boiling* water and to leave it in the vessels for a considerable time to destroy the active forms of bacteria that are sure to be present. Even though the active forms may be killed by boiling water in the course of a few minutes, their spores, which correspond to seeds, will resist boiling temperature for a long time. The danger of contamination from spores is not so great but that it may be neglected for all practical purposes, and unless the vessels are contaminated with some dangerous bacteria, a thorough washing in boiling water is sufficient. But vessels in which milk is to be kept cannot be properly cleaned by pouring boiling water into one, allowing it to remain there for a few minutes, and then pouring it into another, and making one heating of the water suffice for the cleaning of several vessels. The last ones thus treated will not be much cleaner, so far as bacteria are concerned, than if they were washed with cold water. To clean vessels thoroughly, it is necessary to use a higher temperature than that of boiling water, which can be readily obtained by putting them for a few minutes in a hot oven or on a hot stove. If this is thoroughly done, there is no danger of contamination of milk from the milk vessels.

The use of sal-soda in washing milk vessels is advantageous, because it acts chemically upon fatty matters (grease), and thus helps to remove them and other materials which adhere to the vessels with them. In like manner, the use of "live steam" to "dry" vessels after washing, has the advantage of sterilizing them, *i. e.*, killing the bacteria by the highly heated steam. As ordinarily used, however, although live steam is of great value in assisting in cleaning the vessels, it does not completely sterilize them, since its effects are not allowed to continue long enough. Two minutes' action of live steam is not sufficient to kill the bacteria spores which may be hidden in the cracks of the milk vessels.

SUMMARY.

1. Bacteria or microbes, as they are often called, abound in air, water, and soil, in animal and vegetable substances, and in living plants and animals. They are extremely minute and multiply with wonderful rapidity wherever the circumstances are favorable. Cold hinders their development. When heated long enough at the temperature of boiling water, they are killed, but their spores, which correspond to seeds, will endure even this temperature for some time, though higher heat kills them speedily.

2. Bacteria grow with the greatest readiness in milk and cream. Hence they collect in milk and cream exposed to the air, and multiply *rapidly. In developing they cause the milk to sour and curdle and induce other changes in it. They also favor the ripening of cream.*

3. Vessels in which milk and cream are to be kept are a great source of contamination by bacteria. The latter gather upon the sides and in the joints, and develop in the minute portions of milk, grease, or other matters from which it is difficult to free the walls of the vessels completely by washing.

4. A large number of different species of bacteria are found in milk and cream. Different species have different effects. Most of them sour and curdle milk at some temperature. A few induce changes that render milk alkaline without the formation of curd. When a curd is formed, it differs in character with different species of bacteria. The souring of milk is more complex than has been supposed; and while without much doubt souring always depends upon the action of bacteria, any one of a number of species, or several combined, may be the cause.

5. The longer a specimen of milk has been exposed to the action of bacteria, other things being equal, the greater will be the number of bacteria present. Hence it follows that cream will usually contain a very large number. The presence of these organisms, so far from being injurious, is of a positive advantage to the butter-maker, since it is by their action that cream is "ripened."

6. The ripening of cream appears to be even more complex than the souring of milk. While the ripening of cream is undoubtedly dependent upon the presence of bacteria, it is doubtful whether one species can produce what is known as ripened cream. Dairymen let their cream ripen before churning because their experience implies that the butter separates ("comes") more readily, keeps better, and is of better flavor. A plausible explanation is that the bacteria break up the albuminous matter which encloses the particles of butter fat, so that the butter is more readily separated from it, and when made contains less of it. Since this albuminous matter affords support for the bacteria which cause butter to become rancid, it is natural to suppose that butter will keep the better the less it contains.

7. Three important points in the handling of milk and cream are brought out by these considerations:

First. The importance of keeping milk, so far as possible, free from bacteria by the exercise of the greatest cleanliness.

Second. The importance of cooling milk immediately after it is drawn from the cow in order to prevent the souring as long as possible.

Third. The advantage of keeping cream under circumstances favorable to the growth of bacteria that induce ripening.

8. 'In brief, vessels in which milk is to be kept for creaming or for transport should be most carefully cleansed before the milk is put in them. As cold retards, and heat up to certain limits, favors the growth of bacteria, the advantage of keeping milk cold and cream warm is easily explained.

STUBBLE AND ROOTS OF PLANTS AS MANURE.

By Chas. D. Woods.

The investigation upon the amount and fertilizing value of the stubble and roots left behind after the removal of crops, described in the Annual Report of the Station for 1888, has been continued during the year just closed.

The dairy interests in Connecticut are pressing upon the attention of farmers the necessity of forage plants to supplement the common feed of pastures and meadows. During the past season the Station has conducted experiments upon the growth of vetches, lupines, cow peas, beans, and other forage plants with the hope of learning something of their adaptability to the climate and soils of the State. Experiments described elsewhere in this Report, see page 11, prove that some, and imply that many, if not all, of the legumes, to which family all of the above-mentioned plants belong, acquire large amounts of nitrogen from the air.

These plants contain large quantities of protein compounds which serve to form blood and muscle, sinew and bone, and hence are especially valuable as food for stock. As nitrogen is the costliest ingredient of plant food furnished by fertilizers, their power to acquire atmospheric nitrogen gives this family of plants a further value for the farmer. Only part of the plant is harvested and used for fodder; the rest, the stubble and roots, remains to fertilize the soil for succeeding crops. Part of the nitrogen which the plants obtain from the air is, of course, left in the roots and stubble. A special study has been made during the last season of the amount and composition of the stubble and roots of some of these plants. In the case of most of the specimens collected this season, the tops from the same sections have been collected, weighed, and will be analyzed later.

METHODS OF OBTAINING SPECIMENS.

The specimens of stubble and roots for analysis were obtained from portions of the field, or plots, representing as nearly as might be an average condition of the crop grown. After removing weeds and other foreign matter, a trench about two feet deep and large enough for convenience in working, was dug around a small section of earth, leaving a square block in the center a little more than two feet on a side. The sides of this earth block were carefully trimmed until it was exactly two feet square, thus making an area of four square feet, or 1-10890 of an acre. By means of a cord drawn tightly around the block, sections of the required depth were marked off and the earth from each layer removed into a box by itself. The trench was deepened for convenience in working as successive layers were removed.

Each section of the earth from which specimens Nos. 29 to 39 were obtained, was worked over separately by hand labor, the roots, stubble (and in the case of grass, the new growth), being separated from the soil and from the roots of weeds as far as possible. The fine hair-like roots could not all be secured, but the results could not have thus been materially affected. In the case of the other specimens, the earth was sifted as the sections were being dug. The soil was passed through seives of 5-16 or 3-16 inch mesh, according to the fineness of the roots. While some of the fine, fibrous roots passed through the seive, only a very small part, by weight, of the roots were lost, and the work was greatly facilitated. On the whole, though the separation is not quite as complete as by the hand process, the collection of a larger number of specimens was made possible, and the results are nearly, if not quite, as reliable as in the other method.

The specimens were obtained by Prof. Phelps, Vice-Director, and Mr. Bailey, Assistant in Farm Experiments of the Station, with the aid of the senior class of the Storrs School and some outside labor during the summer season.

Through the kindness of Mr. Joseph Merrow, of Mansfield, the Station was able to obtain on his farm specimens of clover, stubble, and roots under very favorable circumstances as to soil and condition of crop.

DESCRIPTION OF SPECIMENS.

29. *Cow Peas, Stubble, and Roots.*—From School farm. The surface soil, to a depth of about seven inches, was a light loam.

Subsoil, yellow and compact; becoming, at a depth of thirty inches, loose and gravelly in texture. The specimen consisted of stubble and such roots as could be pulled out of the soil with the stubble. This included nearly all of the larger roots of the surface soil. This specimen is from three sections, of four square feet each, from a portion of the field which yielded 15,840 pounds of green crop per acre. Weight of specimen, after partial drying in the laboratory, 93 grams, or at the rate of 4,460 pounds per acre. Crop harvested September 27th and 28th. Specimen taken October 3d.

30. *Cow Peas, Stubble, and Roots.*—From same field as M. 29. When received the specimen, from an area of four square feet, weighed as follows:

Stubble and first 6 in. of roots,	38.00 grams, or	912 lbs. per acre.
Second 6 in. of roots (6-12 in.),	1.87 grams, or	45 lbs. per acre.
Third 6 in. of roots (12-18 in.),	2.25 grams, or	54 lbs. per acre.
Fourth 6 in. of roots (18-24 in.),	1.43 grams, or	34 lbs. per acre.
Fifth 6 in. of roots (24-30 in.),	2.62 grams, or	63 lbs. per acre.
Sixth 6 in. of roots (30-36 in.),	2.47 grams, or	59 lbs. per acre.
Seventh 6 in. of roots (36-42 in.),	1.67 grams, or	40 lbs. per acre.
Stubble and total roots (0.42 in.),	50.31 grams, or	1,207 lbs. per acre.
After partial drying, total weight was,	47.89 grams, or	1,150 lbs. per acre.

32. *Timothy and Redtop, Stubble and Roots.*—Soil same as M. 29. Field was mowed July 23d, and yielded about two tons of hay per acre. At the time of collection of specimen the field contained, in addition to the roots and stubble, the rowen, or second growth, which was about three inches high, and was green and luxuriant. The crop was principally timothy, with a slight mixture of redtop. The specimen was taken November 7th from an area of four square feet, and weighed as follows:

Stubble (including rowen) and first 6 in. of roots, 330.9 grams, corresponding to 7,944 lbs. per acre.

33. *Timothy and Redtop Roots.*—Soil as in M. 29. Specimen consisted of roots below a depth of six inches from same section as M. 32. Sample taken November 7th, and weighed as follows:

Roots from second 6 in. (6-12 in.),	15.00 grams, or	360 lbs. per acre.
Roots from third 6 in. (12-18 in.),	9.00 grams, or	216 lbs. per acre.
Roots from fourth 6 in. (18-24 in.),	3.00 grams, or	72 lbs. per acre.
Roots from fifth 6 in. (24-30 in.),	1.00 grams, or	24 lbs. per acre.
Roots from sixth 6 in. (30-36 in.),	0.25 grams, or	6 lbs. per acre.
Roots from 6 to 36 in. in depth,	28.25 grams, or	678 lbs. per acre.
Weight of roots after partial drying,	27.00 grams, or	648 lbs. per acre.

34. *Buckwheat Stubble, and Roots.*—Soil a compact clay loam, with rather more than an average amount of vegetable matter. Subsoil, clayey, compact, and moist. Grown on the farm of the School. Buckwheat was cut September 24th. Roots collected September 29th. Specimen from an area of four square feet weighed as follows:

Stubble and roots from first 6 in.,	20.96 grams, or	503 lbs. per acre.
Roots from second 6 in. (6-12 in.),	0.85 grams, or	20 lbs. per acre.
Stubble and roots from first 12 in.,	21.81 grams, or	523 lbs. per acre.
Weight after partial drying,	21.00 grams, or	504 lbs. per acre.

The third six inches was practically free from roots.

36. *Clover, Stubble and Roots from first six inches.*—From farm of Joseph Merrow, Mansfield. Surface soil a fine alluvial loam, nine inches deep. Sub-soil to depth of three and one-half feet a fine, compact loam, much like the surface soil except in amount of vegetable matter; below this, a fine sand. The roots penetrated to, but none seemed to enter, the sand. The field was seeded to clover with oats in 1888, and gave a heavy yield of fodder this season. At harvesting the clover was in full bloom, a few heads having turned brown. Harvested June 13, roots collected June 13 and 14.

Weight of green tops from this section,	40 ounces, or	27,255 lbs. per acre.
Stubble and roots to depth of 6 inches,	120.8 grams, or	2,900 lbs. per acre.

37. *Clover Roots from depth of six to thirty-six inches.*—From same block as No. 36:

Roots from second 6 in. (6–12 in.),	4.6 grams, or	111 lbs. per acre.
Roots from third 6 in. (12–18 in.),	2.3 grams, or	55 lbs. per acre.
Roots from fourth 6 in. (18–24 in.),	2.0 grams, or	48 lbs. per acre.
Roots from fifth 6 in. (24–30 in.),	1.7 grams, or	41 lbs. per acre.
Roots from sixth 6 in. (30–36 in.),	1.2 grams, or	28 lbs. per acre.
Roots from 6 to 36 in. in depth,	11.8 grams, or	283 lbs. per acre.
Weight of dried (water-free) roots,	11.2 grams, or	268 lbs. per acre.

38. *Clover, Stubble and Roots from first six inches.*—From same field as Nos. 36 and 37, but from slightly higher ground. Surface soil and subsoil to depth of sixteen inches same as in No. 36. Below this, coarse sand, becoming gravel at depth of thirty inches. The roots penetrated to entire depth of this block and were larger and coarser than in the other block from this same field.

Weight of green tops from this section,	44 ounces, or	29,948 lbs. per acre.
Stubble and roots to depth of 6 in.,	42.2 ounces, or	1,013 lbs. per acre.

39. *Clover Roots from depth of six to thirty-six inches.*—From same block as No. 38:

Roots from second 6 in. (6–12 in.),	3.7 grams, or	89 lbs. per acre.
Roots from third 6 in. (12–18 in.),	3.8 grams, or	91 lbs. per acre.
Roots from fourth 6 in. (18–24 in.),	4.2 grams, or	100 lbs. per acre.
Roots from fifth 6 in. (24–30 in.),	3.4 grams, or	80 lbs. per acre.
Roots from sixth 6 in. (30–36 in.),	2.8 grams, or	68 lbs. per acre.
Roots from 6 to 36 in. in depth,	17.8 grams, or	428 lbs. per acre.
Weight of dry (water-free) roots,	17.1 grams, or	410 lbs. per acre.

40. *Yellow Lupine (Lupinus luteus), Stubble and Roots.*—Grown in the Forage Garden of the Station. Surface soil heavy loam, slightly clayey, about eight inches in depth. Subsoil, a yellow clay loam, the amount of clay increasing with the depth. The lupine when harvested was a little past full bloom, and pods were beginning to form. The plants were about two and one-half feet tall, were spreading, leafy and less woody than the other varieties grown. The tops were harvested August 6, and the roots all collected before August 16. The roots were more fibrous than were those of the other varieties.

Weight of green tops from this block,	69¼ ounces, or	47,130 lbs, per acre.
Stubble and roots from first 8 inches,	55.8 grams, or	1,341 lbs. per acre.
Roots from 8 to 18 in. in depth,	5.0 grams, or	119 lbs. per acre.
Roots from 18 to 30 in. in depth,	2.8 grams, or	67 lbs. per acre.
Stubble and roots to depth of 30 in.,	63.6 grams, or	1,527 lbs. per acre.
Dry (water-free) stubble and roots,	59.5 grams, or	1,429 lbs. per acre.

41. *Yellow Lupine (Lupinus luteus), Stubble and Roots.* From Forage Garden. Soil and description of plants same as No. 40. Harvested and roots collected at same time as No. 40.

Weight of green tops from this block,	65 ounces, or	44,240 lbs. per acre.
Stubble and roots to depth of 8 in.,	53.3 grams, or	1,280 lbs. per acre.
Roots from 8 to 18 in. in depth,	4.5 grams, or	109 lbs. per acre.
Roots from 18 to 30 in. in depth,	2.2 grams, or	52 lbs. per acre.
Stubble and roots to depth of 30 in.,	60.0 grams, or	1,441 lbs. per acre.
Dry (water-free) stubble and roots,	56.5 grams, or	1,355 lbs. per acre.

42. *Blue Lupine (Lupinus hirsutus), Stubble and Roots.*—From Forage Garden. Soil and time of collecting same as No. 40. At time of harvest plants were three feet tall, spreading and nearly past flowering; pods and seeds small and immature; roots large and coarse.

Weight of green tops from this block,	51½ ounces, or	35,053 lbs. per acre.
Stubble and roots to depth of 7 inches,	46.6 grams, or	1,119 lbs. per acre.
Roots from 7 to 18 in. in depth,	4.0 grams, or	96 lbs. per acre.

Roots from 18 to 30 in. in depth,	4.6 grams, or	111 lbs. per acre.
Stubble and roots to depth of 30 in.,	55.2 grams, or	1,326 lbs. per acre.
Dry (water-free) stubble and roots,	52.3 grams, or	1,256 lbs. per acre.

43. *Blue lupine (Lupinus hirsutus), Stubble and Roots.*—From Forage Garden. Soil, description of plants, and dates of collecting specimens same as No. 42.

Weight of green tops from this block,	66¼ ounces, or	45,092 lbs. per acre.
Stubble and roots to depth of 7 in.,	57.9 grams, or	1,390 lbs. per acre.
Roots from 7 to 18 in. in depth,	4.2 grams, or	101 lbs. per acre.
Roots from 18 to 30 in. in depth,	3.4 grams, or	82 lbs. per acre.
Stubble and roots to depth of 30 in.,	65.5 grams, or	1,573 lbs. per acre.
Dry (water-free) stubble and roots,	61.8 grams, or	1,483 lbs. per acre.

44. *White lupine (Lupinus alba), Stubble and Roots.* From Forage Garden. Soil and date of collecting same as No. 40. The plants when harvested were three feet tall, coarse, branching, and woody; nearly through flowering; pods and seeds were immature, and roots large and coarse.

Weight of green tops from this block,	35½ ounces, or	24,162 lbs. per acre.
Stubble and roots to depth of 7 inches,	35.3 grams, or	848 lbs. per acre.
Roots from 7 to 18 in. in depth,	5.3 grams, or	127 lbs. per acre.
Roots from 18 to 30 in. in depth,	1.9 grams, or	46 lbs. per acre.
Stubble and roots to depth of 30 in.,	42.5 grams, or	1,021 lbs. per acre.
Dry (water-free) stubble and roots,	40.0 grams, or	962 lbs. per acre.

45. *White lupine (Lupinus alba), Stubble and Roots.*—From Forage Garden. Soil, description of plants, and date of collecting same as No. 44.

Weight of green tops from this block,	34¾ ounces, or	23,652 lbs. per acre.
Stubble and roots to depth of 7 in.,	38.2 grams, or	918 lbs. per acre.
Roots from 7 to 18 in. in depth,	5.4 grams, or	129 lbs. per acre.
Roots from 18 to 30 in. in depth,	1.9 grams, or	46 lbs. per acre.
Stubble and roots to depth of 30 in.,	45.5 grams, or	1,093 lbs. per acre.
Dry (water-free) stubble and roots,	43.0 grams, or	1,034 lbs. per acre.

46. *Horse bean (Vicia Faba), Stubble and Roots.*—From Forage Garden. Soil same as No. 40. Plants were three feet tall; stems large, hollow, and somewhat woody; nearly past flowering; pods and seeds small and immature. Harvested August 16th; roots collected August 17th and 20th.

Weight of green tops from this block,	51½ ounces, or	35,053 lbs. per acre.
Stubble and roots to depth of 8 in.,	70.2 grams, or	1,684 lbs. per acre.
Roots from 8 to 23 in. in depth,	5.9 grams, or	141 lbs. per acre.
Stubble and roots to depth of 23 in.,	76.1 grams, or	1,825 lbs. per acre.
Dry (water-free) stubble and roots,	73.2 grams, or	1,759 lbs. per acre.

47. *Soja bean (Soja hispida), Stubble and Roots.*—From Forage Garden. Soil same as No. 40. Plants were twenty inches tall, spreading, and leafy; pods and seeds quite well formed, but immature. Roots fine and fibrous, abundant near the surface.

Weight of green tops from this block,	28 ounces, or	19,190 lbs. per acre.
Stubble and roots to depth of 7 in.,	27.1 grams, or	651 lbs. per acre.
Roots from 7 to 23 in. in depth,	3.3 grams, or	79 lbs. per acre.
Stubble and roots to depth of 23 in.,	30.4 grams, or	730 lbs. per acre.
Dry (water-free) stubble and roots,	29.2 grams, or	701 lbs. per acre.

48. *Vetch (Vicia sativa), Stubble and Roots.*—From Forage Garden. Soil same as No. 40. Plants were low and spreading, nearly covering the ground between the rows, which were three feet apart. Plants were harvested and roots collected August 23d.

Weight of green tops from this block,	36½ ounces, or	24,843 lbs. per acre.
Stubble and roots to depth of 8 in.,	49.9 grams, or	1,198 lbs. per acre.
Roots from 8 to 22 in. in depth,	7.9 grams, or	192 lbs. per acre.
Stubble and roots to depth of 22 in.,	57.8 grams, or	1,390 lbs. per acre.
Dry (water-free) stubble and roots,	55.7 grams, or	1,401 lbs. per acre.

49. *Vetch (Vicia sativa), Stubble and Roots.*—From Forage Garden. Soil, description of plant, and date of collecting same as No. 48.

Weight of green tops from this block,	34 ounces, or	23,141 lbs. per acre.
Stubble and roots to depth of 8 in.,	56.9 grams, or	1,366 lbs. per acre.
Roots from 8 to 22 in. in depth,	10.2 grams, or	245 lbs. per acre.
Stubble and roots to depth of 22 in.,	67.1 grams, or	1,611 lbs. per acre.
Dry (water-free) stubble and roots,	64.6 grams, or	1,555 lbs. per acre.

50. *Mammoth Red Clover (Trifolium pratense), Stubble and Roots.*—From Forage Garden. Surface soil, heavy clay loam, moist and compact. Subsoil stiff clay, increasing in compactness with depth, becoming hard-pan at a depth of thirty inches. Seed sown in spring of 1889. Plants thinned out in summer. There was a thick, heavy growth, twenty inches tall, and in full bloom at harvest. Harvested and roots collected August 23d. Very few roots in last six inches.

Weight of green tops from this block,	30 ounces, or	20,419 lbs. per acre.
Stubble and roots to depth of 6 in.,	70.5 grams, or	1,693 lbs. per acre.
Roots from 6 to 24 in. in depth,	5.1 grams, or	122 lbs. per acre.
Stubble and roots to depth of 24 in.,	75.6 grams, or	1,815 lbs. per acre.
Dry (water-free) stubble and roots,	72.6 grams, or	1,743 lbs. per acre.

51. *Mammoth Red Clover (Trifolium pratense), Stubble and Roots*—From Forage Garden. Soil, description of plants, and date of collecting same as No. 50.

Weight of green tops from this block,	42¼ ounces, or	28,757 lbs. per acre.
Stubble and roots to depth of 6 in.,	110.1 grams, or	2,643 lbs. per acre.
Roots from 6 to 24 in. in depth,	6.7 grams, or	161 lbs. per acre.
Stubble and roots to depth of 24 in.,	116.8 grams, or	2,804 lbs. per acre.
Dry (water-free) stubble and roots,	112.1 grams, or	2,692 lbs. per acre.

52. *Cow Pea (Dolichos sinensis), Stubble and Roots.*—Grown by the Station on the School Farm. Surface soil, light loam, eight inches deep. Subsoil, a yellow, compact loam, becoming sandy and gravelly at a depth of thirty-two to thirty-four inches. The roots were large and coarse and penetrated the entire block of earth, and in small numbers to even greater depth. Crop harvested September 27th; roots dug September 28th.

Stubble and roots to depth of 8 in.,	67.4 grams, or	1,618 lbs. per acre.
Roots from 8 to 28 in. in depth,	18.0 grams, or	432 lbs. per acre.
Stubble and roots to depth of 28 in.,	85.4 grams, or	2,050 lbs. per acre.
Dry (water-free) stubble and roots,	82.0 grams, or	1,969 lbs. per acre.

53. *Cow Pea (Dolichos sinensis), Stubble and Roots.*—From same field as No. 52.

Stubble and roots to depth of 8 in.,	67.3 grams, or	1,616 lbs. per acre.
Roots from 8 to 28 in. in depth,	16.3 grams, or	391 lbs. per acre.
Stubble and roots to depth of 28 in.,	83.6 grams, or	2,007 lbs. per acre.
Dry (water-free) stubble and roots,	79.3 grams, or	1,904 lbs. per acre.

Table 14, which follows, recapitulates the principal statistics contained in the description of specimens. The weights in the first four columns are in grams, and represent the weight of the stubble and roots, freed as completely as practicable from sand and other adhering foreign matter, actually found in the areas examined. The specimens were dried for twenty-four hours at 90° C. (194° F.), and afterwards exposed to the atmosphere of the laboratory for ten or twelve hours, in order that they might absorb enough water to make their moisture content nearly in equilibrium with that of the air of the laboratory. The specimens thus treated contained about five per cent. of water. It is this condition that is called "air dry" in the table. Afterwards the water in the "air dry" specimens was determined and the weight of dry matter (water-free) was calculated. This weight is given in the fifth, and in the last column in the table. The last four columns contain the weights of stubble and roots, expressed in pounds, as calculated to the acre.

TABLE 14.

Weight of Stubble and Roots.

KIND OF PLANT.	Laboratory Number.	IN FOUR SQUARE FEET.				IN ONE ACRE.			
		Stubble and roots of surface soil. *Air dry weights.*	Roots of sub-soil. *Air dry Weights.*	Total stubble and roots. *Air dry Weights.*	Total stubble and roots. *Dry (water-free) weights.*	Stubble and roots of surface soil. *Air dry weights.*	Roots of subsoil. *Air dry weights.*	Total stubble and roots. *Air dry weights.*	Total stubble and roots. *Dry (water-free) weight.*
		G.	G.	G.	G.	Lbs.	Lbs.	Lbs.	Lbs.
Timothy and Redtop,	32–3	*(1)* 330.9	*(2)* 28.3	359.2	343.7	*(1)* 7944	*(2)* 678	8622	8223
Buckwheat,	34	*(1)* 21.6	*(3)* 1.0	22.0	20.1	*(1)* 503	*(3)* 20	523	483
Cow Pea,	30	*(1)* 38.0	*(4)* 12.3	50.3	45.6	*(1)* 912	*(4)* 295	1207	1095
Cow Pea,	52	*(5)* 67.4	*(6)* 18.0	85.4	82.0	*(5)* 1618	*(6)* 432	2050	1969
Cow Pea,	53	*(5)* 67.3	*(6)* 16.3	83.6	79.3	*(5)* 1616	*(6)* 391	2007	1904
Average of 30, 52 and 53,		57.6	15.5	73.1	69.0	1382	373	1755	1656
Clover,	36–7	*(1)* 120.8	*(2)* 11.8	132.6	121.1	*(1)* 2900	*(2)* 283	3183	2907
Clover,	38–9	*(1)* 42.2	*(2)* 17.9	60.1	56.8	*(1)* 1013	*(4)* 428	1441	1365
Average of 36–7 and 38–9,		81.5	14.9	96.4	90.0	1957	356	2313	2136
Clover,	50	*(1)* 70.5	*(7)* 5.1	75.6	72.6	*(1)* 1693	*(7)* 122	1815	1743
Clover,	51	*(1)* 110.1	*(7)* 6.7	116.8	112.1	*(1)* 2643	*(7)* 161	2804	2692
Average of 50 and 51,		90.3	5.9	96.2	92.4	2168	142	2310	2218
Clover, average of four,		85.9	10.4	96.3	91.2	2055	250	2305	2177
Vetch,	48	*(5)* 49.9	*(8)* 7.9	57.8	55.7	*(5)* 1198	*(8)* 192	1390	1401
Vetch,	49	*(5)* 56.9	*(8)* 10.2	67.1	64.6	*(5)* 1366	*(8)* 245	1611	1555
Average of 48 and 49,		53.4	9.1	62.5	60.2	1282	219	1501	1478
Yellow Lupine,	40	*(5)* 55.8	*(9)* 7.8	63.6	59.5	*(5)* 1340	*(9)* 187	1527	1429
Yellow Lupine,	41	*(5)* 53.3	*(9)* 6.7	60.0	56.4	*(5)* 1280	*(9)* 161	1441	1355
Average of 40 and 41,		54.6	7.3	61.9	78.0	1310	174	1484	1392
Blue Lupine,	42	*(10)* 46.6	*(11)* 8.6	55.2	52.3	*(10)* 1119	*(11)* 207	1326	1256
Blue Lupine,	43	*(10)* 57.9	*(11)* 7.6	65.5	61.8	*(10)* 1390	*(11)* 183	1573	1483
Average of 42 and 43,		52.3	8.6	60.9	57.1	1255	195	1445	1370
White Lupine,	44	*(10)* 35.3	*(11)* 7.2	42.5	40.1	*(10)* 848	*(11)* 173	1021	962
White Lupine,	45	*(10)* 38.3	*(11)* 7.2	45.5	43.1	*(10)* 918	*(11)* 175	1093	1035
Average of 44 and 45,		36.8	7.2	44.0	41.6	883	174	1057	998
Horse Bean,	46	*(5)* 70.2	*(12)* 5.9	76.1	73.2	*(5)* 1684	*(12)* 141	1825	1759
Soja Bean,	47	*(10)* 27.1	*(13)* 3.3	30.4	29.2	*(10)* 651	*(13)* 79	730	701

(1) First six inches. *(2)* Thirty inches, 6–36 in. *(3)* Six inches, 6-12 in. *(4)* Thirty-six inches, 6–42 in. *(5)* First eight inches. *(6)* Twenty inches, 8–28 in. *(7)* Eighteen inches, 6–24 in. *(8)* Fourteen inches, 8–22 in. *(9)* Twenty-two inches, 8–30 in. *(10)* First seven inches. *(11)* Twenty-three inches, 7–30 in. *(12)* Fifteen inches, 8–23 in. *(13)* Sixteen inches, 7–23 in.

TABLE 15.

Composition of Stubble and Roots.

KIND OF PLANT AND PORTION ANALYZED.	Laboratory Number.	IN WATER-FREE SUBSTANCE.				IN PURE ASH.	
		Organic Matter.	Crude Ash.	Pure Ash.	Nitrogen.	Phosphoric Acid, (P_2O_5)	Potash, (K_2O)
		%	%	%	%	%	%
Timothy and redtop, stubble and roots to depth of 6 in., - -	32	82.36	17.64	4.30	1.10	7.28	16.35
Timothy and redtop, roots below 6 in. to depth of 3 feet, - -	33	67.59	32.41	5.57	1.04	4.17	6.62
Buckwheat, stubble and roots, -	34	75.42	24.58	6.29	.91	4.32	12.80
Cow pea, stubble and roots pulled with stubble, - - - -	29	93.69	6.31	4.13	1.40	9.27	18.37
Cow pea, stubble and roots to depth of 3½ feet, - - -	30	77.71	22.29	4.91	1.32	5.22	11.88
Cow pea, stubble and roots to depth of 28 in., - - -	52	76.76	23.24	5.82	1.39	6.42	14.42
Cow pea, stubble and roots to depth of 28 in., - - -	53	80.11	19.89	5.63	1.36	6.95	19.18
Average of Nos. 30, 52 and 53,	—	78.19	21.81	5.45	1.36	6.20	15.16
Clover, stubble and roots to depth of 6 in., - - - - -	36	71.94	28.06	7.16	2.09	7.24	22.40
Clover, stubble and roots to depth of 6 in., - - - - -	38	64.24	35.76	7.54	1.88	10.54	11.70
Average of Nos. 36 and 38, -	—	68.09	31.91	7.35	1.99	8.89	17.05
Clover, roots below 6 in. to depth of 3 feet, - - - - -	37	72.26	27.74	6.61	1.88	7.76	17.31
Clover, roots below 6 in. to depth of 3 feet, - - - - -	39	44.09	55.91	6.99	1.18	4.94	10.41
Average of Nos. 37 and 39, -	—	58.17	41.83	8.80	1.53	6.35	13.86
Clover, stubble and roots to depth of 2 feet, - - - - -	50	71.57	28.43	7.74	2.22	7.35	19.39
Clover, stubble and roots to depth of 2 feet, - - - - -	51	70.25	29.75	8.71	2.06	6.88	19.55
Average of Nos. 50 and 51, -	—	70.91	29.09	8.23	2.14	7.22	19.47
Vetch, stubble and roots to depth of 22 in., - - - - -	48	65.44	34.56	8.33	1.93	6.19	13.63
Vetch, stubble and roots to depth of 22 in., - - - - -	49	58.81	41.19	7.74	1.75	5.93	23.04
Average of Nos. 48 and 49, -	—	62.12	37.88	8.04	1.84	6.06	18.34
Yellow lupine, stubble and roots to depth of 30 in., - - -	40	80.83	19.17	6.44	1.10	5.31	25.43
Yellow lupine, stubble and roots to depth of 30 in., - - -	41	78.93	21.07	5.86	1.22	7.61	25.21
Average of Nos. 40 and 41, -	—	79.88	20.12	6.15	1.16	6.46	25.32

TABLE 15. (*Continued.*)

KIND OF PLANT AND PORTION ANALYZED.	Laboratory No.	IN WATER-FREE SUBSTANCE.				IN PURE ASH.	
		Organic Matter.	Crude Ash.	Pure Ash.	Nitrogen.	Phosphoric Acid, (P_2O_5)	Potash, (K_2O).
Blue lupine, stubble and roots to depth of 30 in.,	42	78.25	21.75	6.66	.85	3.42	14.89
Blue lupine, stubble and roots to depth of 30 in.,	43	81.87	18.13	6.45	.80	3.26	26.63
Average of Nos. 42 and 43,	—	80.06	19.94	6.56	.83	3.34	20.76
White lupine, stubble and roots to depth of 30 in.,	44	77.87	22.13	6.86	.97	2.73	17.53
White lupine, stubble and roots to depth of 30 in.,	45	80.05	19.95	6.68	1.07	2.80	15.55
Average of Nos. 44 and 45,	—	78.96	21.04	6.77	1.02	2.77	16.54
Horse bean, stubble and roots to depth of 23 in.,	46	78.12	21.88	6.15	1.81	5.61	18.09
Soja bean, stubble and roots to depth of 23 in.,	47	80.90	19.10	5.30	1.22	5.98	15.27

Table 15, which precedes, gives the percentages of the more important constituents found in the specimens of stubble and roots. The methods of analysis were described in the Report of this Station for 1888, pp. 34–35. Nitrogen was determined by the method of Kjeldahl, potash by the method of Lindo as modified by Gladding, and phosphoric acid by the ammonium molybdate method, all three as recommended by the Association of Official Agricultural Chemists. Crude ash, organic matter, nitrogen and pure ash are calculated to the dry (water-free) stubble and roots. The percentages of phosphoric acid and potash are given as determined in the pure ash.

That different kinds of plants should show great differences in their chemical constitution was to be expected, and even in different specimens of the same species of plants the adhering sand would vary in amount. This would give varying percentages of crude ash and produce a corresponding difference in the percentages of organic matter, nitrogen, and pure ash as referred to the dry specimens. It was also to be expected that the pure ash would show some variations even in the same species of plants, but such varying amounts of potash as were found in some cases were quite unexpected. In every case the determinations were made in duplicate, and where these variations have appeared the analyses have been repeated and the results verified.

TABLE 16.

Amount of Roots and Stubble and Valuable Ingredients left in One Acre, with Valuable Ingredients in Manures.

KIND OF PLANT AND PORTION ANALYZED.	Laboratory Number.	Roots and Stubble (water-free)	Nitrogen.	Phosphoric Acid, (P_2O_5)	Potash, (K_2O)
Reported herewith.		Lbs.	Lbs.	Lbs.	Lbs.
Timothy and redtop, stubble and roots to depth of 6 inches, - - - - - -	32	7606	83.7	23.8	53.5
Timothy and redtop, roots below 6 inches to depth of 3 feet, - - - - - -	33	617	6.4	1.4	2.3
Timothy and redtop, stubble and total roots to depth of 3 feet, - - - - - -	32–3	8223	90.1	25.2	55.8
Buckwheat, stubble and roots to depth of 1 foot, - - - - - - - -	34	483	4.4	1.3	3.8
Cow pea, stubble and roots pulled with stubble, - - - - - - -	29	711	10.0	2.7	5.3
Cow pea, stubble and roots to depth of 3 feet,	30	1095	14.5	2.8	6.4
Cow pea, stubble and roots to depth of 28 inches, - - - - - - - -	52	1969	27.4	7.4	16.5
Cow pea, stubble and roots to depth of 28 inches, - - - - - - - -	53	1904	25.9	7.5	20.6
Average of Nos. 30, 52 and 53, - -	—	1656	22.6	5.9	14.5
Clover, stubble and roots to depth of 6 inches,	36	2638	55.1	13.7	42.3
Clover, stubble and roots to depth of 6 inches,	38	955	18.0	7.6	8.4
Average of Nos. 36 and 38, - -	—	1797	36.6	10.7	25.4
Clover, roots below 6 inches to depth of 3 feet,	37	268	5.1	1.4	3.1
Clover, roots below 6 inches to depth of 3 feet,	39	410	4.8	1.4	3.0
Average of Nos. 37 and 39, - -	—	339	5.0	1.4	3.1
Clover, stubble and total roots to depth of 3 feet, Nos. 36 and 37, - - - - -	—	2906	60.2	15.1	45.4
Clover, stubble and total roots to depth of 3 feet, Nos. 38 and 39, - - - - -	—	1365	22.8	9.0	11.4
Average of last two, - - - - -	—	2136	41.5	12.1	28.4
Clover, stubble and roots to depth of 2 feet,	50	1743	38.7	9.9	26.2
Clover, stubble and roots to depth of 2 feet,	51	2692	55.4	16.1	45.9
Average of Nos. 50 and 51, - -	—	2218	47.1	13.0	36.1
Clover, total roots and stubble, average of above four samples, - - - - -	—	2177	44.3	12.5	32.2
Vetch, stubble and roots to depth of 22 inches, - - - - - - - -	48	1401	27.1	7.2	15.9
Vetch, stubble and roots to depth of 22 inches, - - - - - - - -	49	1555	27.2	7.2	27.7
Average of Nos. 48 and 49, - -	—	1478	27.2	7.2	21.8
Yellow lupine, stubble and roots to depth of 30 inches, - - - - - - -	40	1429	15.7	4.9	23.4
Yellow lupine, stubble and roots to depth of 30 inches, - - - - - - -	41	1355	16.5	6.0	20.0
Average of Nos. 40 and 41, - -	—	1392	16.1	5.5	21.7

TABLE 16. *(Continued.)*

KIND OF PLANT AND PORTION ANALYZED.	Laboratory Number.	Roots and Stubble.	Nitrogen.	Phosphoric Acid, (P_2O_5)	Potash, (K_2O)
		Lbs.	Lbs.	Lbs.	Lbs.
Blue lupine, stubble and roots to depth of 30 inches,	42	1256	10.7	2.9	12.5
Blue lupine, stubble and roots to depth of 30 inches,	43	1483	11.9	3.1	25.5
Average of Nos. 42 and 43,	—	1370	11.3	3.0	19.0
White lupine, stubble and roots to depth of 30 inches,	44	962	9.3	1.8	11.6
White lupine, stubble and roots to depth of 30 inches,	45	1034	11.0	1.9	10.7
Average of Nos. 44 and 45,	—	998	10.2	1.9	11.2
Horse bean, stubble and roots to depth of 22 inches,	46	1759	31.8	6.1	19.5
Soja bean, stubble and roots to depth of 22 inches,	47	701	8.6	2.2	5.7
Middletown Station (W. O. Atwater, 1878).					
Timothy. Roots,	—	2240	31.1	7.0	8.4
Wheat. Roots,	—	658	6.4	1.5	2.6
Clover. Roots,	—	1335	35.5	10.0	15.0
Dr. Voelker, England.					
"Good Clover." First year. Roots,	—	4155	100.0	—	—
"Bad Clover." First year. Roots,	—	1550	31.0	—	—
"Thin Clover." Second year. Roots,	—	7026	66.0	29.5	—
"Good Clover." Second year. Roots,	—	6503	65.0	27.0	—
Clover. First year. Mown twice. Roots,	—	1493	24.5	—	—
Clover. First year. Mown once. Roots,	—	3622	51.5	—	—
Dr. Weiske, Germany.		Air dry			
Rye. Roots and stubble,	—	3400	62.0	24.0	30.0
Barley. Roots and stubble,	—	1515	22.0	11.0	9.0
Oats. Roots and Stubble,	—	2200	25.0	28.0	24.0
Wheat. Roots and stubble,	—	2240	22.0	11.0	17.0
Red clover. Roots and stubble,	—	6580	180.0	71.0	77.0
Buckwheat. Roots and stubble,	—	1630	45.0	10.0	9.0
Peas. Roots and stubble,	—	2400	53.0	14.0	11.0
Lupine. Roots and stubble,	—	2800	58.0	13.0	16.0
Fertilizers.		Fertilizers.			
Rich stable manure,*	—	2000	10	10	8
Nitrate of soda,	—	100	16	—	—
Dissolved bone-black,	—	100	—	16	—
Ground bone,*	—	100	3	22	—
Muriate of potash,	—	100	—	—	50

* Analyses taken from Farmers' Annual, 1882. Jenkins and Armsby.

The variability in the weights of stubble and roots, even of the same kind of plants and from the same field is very noticeable. The four specimens of clover illustrate this (see Table 14, p. 75). Nos. 36–7 and 38–9 were from one field and Nos. 50 and 51 from another. In the case of the first two the difference is partly due to the lapse of time between the collection and separation of roots in No. 37. This was delayed for some weeks and the stubble had softened somewhat and had apparently diminished in amount, but it does not seem likely that all of the difference can be attributed to this incipient decay. In Nos. 50 and 51 the difference is large, larger than the difference in the weight of the green crop would lead one to expect. In all four cases great care was taken to leave the same height of stubble and about the same in amount as would be left in ordinary practice. These variations point out the difficulty of securing an exact representation of the amount of stubble and roots remaining in a field, and enforce the desirability of increasing the number of observations.

Of course the amount of stubble would vary with the manner of harvesting the crop. In the case of such plants as grass, a new growth starts as soon as the crop is removed, and this increases with the length of time between harvesting and collecting samples, or ploughing under in farm practice.

Table 16 above is the most important, giving as it does the weight of the valuable ingredients of plant food left in one acre after the removal of the crop. It includes the work here reported upon together with observations made elsewhere. For comparison, the weights of valuable plant food contained in a few standard fertilizers are appended to the table. All that has been said above as to the variability of samples applies with equal force to this table, and adds emphasis to the statement made in the Report of 1888: "These facts tend to make uncertain many lessons that might be drawn from these tables; indeed, perhaps the most important fact here brought out is the need of more observations."

PRACTICAL CONCLUSIONS AND INFERENCES.

When the stubble is turned under, both it and the roots decompose and their manurial ingredients become more or less speedily and completely available for succeeding crops. The crop that leaves a large amount of these materials in and upon the soil after harvest adds much to the next year's store of plant food, and hence to the fertility of the soil.

In the case of plants that send up a new growth after the principal crop has been removed, the amount of roots and stubble, and plant food in them will increase with the growth. In the sample of timothy stubble and roots, the large amount of nitrogen, phosphoric acid, and potash remaining in and upon the land was due to the luxuriant aftergrowth that was present when the specimen was collected.

The stubble and roots of turf land, while not having large percentages of the valuable ingredients of plant food, yet with the great amount of stubble and new growth that is ploughed under, yield a great deal of manurial matter. This may explain why crops do so well when planted upon turf. In one of the field experiments conducted for the Station, the field selected was covered with a heavy sod at the time of ploughing. The plots to which no manure was applied yielded at the rate of over fifty bushels of shelled corn to the acre. Part of the plant food that made this possible came from previous manuring, but doubtless a great deal of it was supplied by the roots and stubble.

As might be expected, the amount of roots and stubble vary with different crops and even with the same kind of crop under different circumstances. The ratio between the amounts of roots and of tops is extremely variable, still it is probably true in general that the greater the amount of the crop of a given plant the greater will be the amount of roots and stubble left behind. But a small crop of one plant, as clover, may leave more fertilizing material in the soil than a large one of another plant like wheat.

Clover roots and stubble contain large percentages of the three most valuable ingredients of plant food, nitrogen, phosphoric acid, and potash, and as clover leaves a large amount of roots and stubble in and upon the soil, it adds greatly to the store of fertilizing material for future use. As will be seen from the table, Dr. Weiske, of Germany, found a little over three tons of stubble and roots per acre remaining from a crop of clover. This contained 180 pounds of nitrogen, 71 pounds phosphoric acid, and 77 pounds of potash. From the composition of fertilizers as given in the above table, it would require over 1,000 pounds of nitrate of soda, 400 pounds of dissolved bone-black, and 150 pounds of muriate of potash to furnish the same amount of fertilizing materials. The average of the four samples of clover herewith reported upon give over one ton of stubble and roots, containing 44 pounds nitrogen, 12½ pounds phosphoric acid, and 32 pounds potash. It should be borne in mind, however, that in such fertilizers as nitrate of soda and superphosphate the plant food is ready for use at once. In roots and stubble, as in stable manure, chemical changes are first needed to make the ingredients available to the plants that feed upon them. Hence a pound of nitrogen would be worth more for immediate use in nitrate of soda than in roots or in stable manure, because it brings a quicker return in the crop.

The cow pea in these experiments did not leave as much per acre as the clover, yet it furnishes a very considerable amount of valuable manure. The crop from which samples Nos. 29 and 30 were taken was small. The field from which samples Nos. 52 and 53 were procured is a fair representation of the amount of growth that may reasonably be expected in this latitude. The amount of nitrogen contained in the stubble and roots from this field is 27 pounds, or more than one-third of the nitrogen removed by a crop of corn yielding 50 bushels of shelled corn and a ton and a half of stalks per acre.

The samples of vetch, while not yielding so great a weight of stubble and roots as the cow pea, contained about the same amount of plant food.

The lupines did not yield large crops and probably with a better growth of tops the amount of the plant food of the stubble and roots would approach that found by Dr. Weiske, in which case they would furnish a large amount of fertilizing materials.

PRACTICAL SUMMARY.

Clover, cow pea, vetches and other legumes have a peculiar power of gathering plant food, and especially nitrogen, from natural sources. Although they contain much more nitrogen than wheat, oats, and similar grains, they thrive and bring large yields where wheat will not. While their faculty for gathering nitrogen from the stores in the soil and especially from the air is not yet explained, the important fact here is that they do gather it and leave a great deal of it in the roots and stubble. Nitrogen is the costliest ingredient of fertilizers. These facts help to explain the economy of clover for manure, and why clover is so valuable as a preparatory crop for wheat and other grains. The above cited facts would seem to imply that the legumes, such as clover, cow peas, and lupines, are especially valuable for this kind of manuring; that timothy and other grasses stand next; and that the grain crops leave the least amounts of plant food in roots and stubble.

METEOROLOGICAL OBSERVATIONS.

By C. S. Phelps.

It is of importance to the farmer to have at hand such data on the weather as will aid him in ascertaining what part of his successes and failures are due to the season, and what part to circumstances more directly under his control. The season is a most important factor in the production of crops.

The value of weather observations, depends, first, on the accuracy of the instruments, and the regularity and care exercised in their use, and second, on the number of years that the observations have been conducted. Our equipment consists of the ordinary instruments for obtaining temperatures, pressure of the air, humidity, rainfall, snowfall, and velocity of the wind, uniform with those in use by the United States Signal Service. The thermometers and barometer are placed in a small thermometer house, especially constructed for the purpose with sides and bottom of open shutters and lattice. The roof is double, and insulated by a dead air space and by asbestos paper beneath the shingles. The house is firmly set two and one-half feet above the ground, and at a sufficient distance from any building or tree to allow free exposure to all points of the compass.

Three times daily, at 7 A. M., 2, and 9 P. M., the temperature, pressure, relative humidity of the air, direction and force of wind, general state of the weather, and amount of rain, if any has fallen, are recorded. In addition to these observations, the maximum and minimum temperatures for the previous twenty-four hours are recorded at 9 P. M. The average of the tri-daily readings, using the 9 P. M. reading twice, is found to give very nearly the average temperature of the twenty-four hours. The average of the maximum and minimum correspond very closely to this, but it is not considered quite as accurate as the former method, for obtaining the daily mean. Monthly blanks furnished by the New England Meteorological Society are filled out at the close of each month, one copy being sent to the Society, and another put on file at the Station.

The Station, and most of the farmers conducting experiments under our supervision, have made weekly crop reports to the above Society during the greater part of the growing season. In return they have received Weekly Crop Bulletins, published by the Society in co-operation with the United States Signal Service. These bulletins were sent out on Monday of each week, during the months of June, July, August, and September. They gave the general condition of crops and the state of the weather for the previous week, in all of the New England States, and have been read with much interest by all receiving them.

The rainfall (50.26 in.) for the year was but little in excess of the average. The annual rainfall for Connecticut covering an average period of 23 years, as obtained at six regular stations of the New England Meteorological Society, is found to be 48.7 inches. Deduct the excess for July above the normal and the year's rainfall would drop about five inches below the average. July was the only month with an unusual amount of rain. The variations for the month are very large, New Haven records 17.08 inches, while from New London 6.91 inches is reported. Some observers report the largest amount ever recorded in a single month.

The year opened with very mild weather, January being one of the warmest on record. Most of the precipitation occurred as rain.

February was cold and dry. The temperature for the month fell 5.6° below the average for the State.

March was warm and at its close the season was farther advanced than common. Ploughing had begun in some places.

The spring opened early. Oats were sown about ten days earlier than in 1888. Spring work was well advanced by May 15th. Frost occured on May 4th, being the last of the season to do any damage.

The summer as a whole was cool and very moist. The excessive rainfall delayed harvesting and much hay and grain was badly damaged.

September was very moist, the relative humidity of the air being greater than for any other month during the year. The actual rainfall, however, was not heavy. The first frost occurred on the 23d, leaving a growing season of 142 days since the last frost in the spring.

October was cool throughout. The mean temperature fell nearly 11° below the average for the month.

The last two months of the year were warm, December being one of the warmest on record. The average temperature for that month, throughout the State, is recorded as 27.3°, while the Station records give 35.1° for December, 1889.

Through the kindness of the officers of the New England Meteorological Society we are able to publish the rainfall from their stations. Table 17 gives the rainfall as recorded during the growing season in twenty localities in the State. Table 18 gives the summary of observations made by the Station at Mansfield.

TABLE 17.

Rainfall During Six Months Ending Oct. 31, 1889.

OBSERVATIONS MADE AT TWENTY LOCALITIES IN THE STATE.

LOCALITY.	OBSERVER.	INCHES PER MONTH.						
		May.	June.	July.	Aug.	Sept.	Oct.	Total.
Falls Village, -	M. H. Dean, - -	4.58	4.31	9.49	2.60	4.47	3.55	29.00
Waterbury, -	N. J. Welton, -	4.64	4.09	10.83	2.76	4.26	4.03	30.61
Oxford, - -	H. R. Stevens, -	3.51	4.00	14.19	5.55	4.85	4.37	36.47
Shelton, - -	F. B. Wheeler, -	4.05	2.87	15.55	2.27	6.28	3.89	34.91
New Haven, -	Signal Station, -	3.81	3.17	17.08	4.38	4.98	3.96	37.38
Wallingford, -	Mrs. D. F. Harrison,	4.18	4.06	13.58	5.22	5.02	4.45	36.51
New Britain, -	A. C. Blake, - -	*2.97	4.30	11.03	3.17	4.29	4.97	—
Hartford, - -	Rev. S. Hart, -	4.13	3.69	10.97	3.11	3.13	6.38	31.41
West Simsbury, -	S. T. Stockwell, -	—	3.20	8.67	3.42	4.66	4.01	—
Canton, - -	G. J. Case, - -	4.11	3.27	9.07	3.71	6.80	4.29	31.25
Vernon, - -	E. H. Lathrop, -	2.25	2.58	9.76	3.13	2.87	—	—
So. Manchester, -	K. B. Loomis, -	3.02	3.61	11.09	4.04	3.24	5.41	30.41
Middletown, -	H. D. A. Ward, -	3.33	3.34	13.43	5.12	4.72	5.47	35.41
New London, -	Signal Station, -	3.84	4.13	6.91	4.15	4.93	5.25	29.21
Lebanon, - -	J. H. Tucker, -	—	—	11.37	5.04	6.15	5.86	—
Mansfield, - -	E. A. Bailey, - -	2.16	3.50	11.39	3.78	4.00	5.52	30.35
No. Woodstock,	L. H. Healey, -	3.70	2.94	11.34	3.56	2.90	4.20	28.64
So. Woodstock, -	L. J. Wells, - -	3.49	2.98	11.24	3.70	3.04	4.74	29.19
Voluntown, -	Rev. E. Dewhurst, -	3.82	2.77	9.35	5.38	7.07	4.30	32.69
Clark's Falls, -	J. B. Perry, - -	5.10	4.20	10.58	4.40	5.74	5.13	35.15
Averages, -	- - - - -	3.75	3.53	11.35	3.92	4.67	4.73	32.41

* Observations began on the 15th.

TABLE 18.

Meteorological Summary for 1889.

OBSERVATIONS MADE AT THE STATION, BY E. A. BAILEY.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
Highest barometer, - - - - -	30.60	30.85	30.49	30.44	30.36	30.48	30.27	30.29	30.34	30.45	30.63	30.93	30.47
Lowest barometer, - - - - -	29.16	29.43	29.06	29.36	29.63	29.54	29.62	29.76	29.44	29.57	29.34	29.19	29.52
Mean barometer, - - - - - -	30.01	30.10	29.87	29.97	29.97	30.01	29.98	30.08	30.05	30.03	30.05	30.12	30.02
Highest temperature, - - - - -	56.8	48.9	59.8	68.2	86.8	86.4	85.8	81.0	80.8	67.9	62.0	62.6	70.6
Lowest temperature, - - - - -	4.9	−6.5	17.0	26.0	32.0	40.9	49.3	46.2	36.0	26.9	14.5	5.0	24.4
Mean temperature, - - - - -	30.8	22.1	34.9	45.6	58.4	65.2	67.9	64.8	59.7	45.8	40.9	35.1	47.6
Relative humidity, - - - - -	—	—	—	—	75.2	81.9	84.4	82.5	85.1	77.9	77.4	77.3	Total.
Total precipitation, - - - - -	4.03	1.64	1.96	3.49	2.16	3.50	11.39	3.78	4.00	5.52	5.91	2.88	50.26
No. of days with precipitation of .01 inches or more, - - -	10	12	10	12	8	10	13	9	14	13	13	17	141
No. of clear observations, - - -	52	47	36	38	53	43	45	56	34	35	34	43	—
No. of cloudy observations, - - -	36	33	47	40	37	38	41	37	51	52	47	46	—
Total movement of wind in miles, -	—	—	—	—	—	—	—	4729	6683	7337	7120	8795	—
Maximum velocity, - - - - -	—	—	—	—	—	—	—	28	30	40	35	62	—

CO-OPERATIVE FIELD EXPERIMENTS WITH FERTILIZERS.

By C. S. Phelps.

The Station has continued its field experiments during 1889 on the same general plan as that adopted soon after its organization in the spring of 1888. In their plan and scope they are essentially the same as those since recommended to the Stations by a convention of Station Directors held in Washington in March in 1889, and published by the Office of Experiment Stations as Circular No. 7, March, 1889.

The experiments have been mainly of two kinds: "Soil Tests" and "Special Nitrogen Experiments." The aim has been to distribute the experiments over a wide extent of territory, and upon different kinds of soils.

The objects of the experiments may be stated briefly as follows:

1. To work directly upon farm lands in different parts of the State, and aid the owners in learning the deficiencies of their soils and the requirements of their crops.

2. To help farmers in becoming familiar with the forms and action of fertilizing materials, containing phosphoric acid, potash and nitrogen.

3. To encourage a spirit of investigation; and thus to gradually develop a number of farm experimenters, whose work will be useful not only to themselves, but in a larger degree to their communities and to the agriculture of the State.

The degree of interest manifested in the work by farmers in general is very encouraging, and the care and accuracy exercised by those to whom the work has been entrusted is all that could be expected.

Very few total failures have resulted, and these were not due to neglect on the part of the experimenters. The experiments with potatoes, which promised well in the early part of the season, were interfered with by the blight. Bordeaux mixture was used as a remedy with reasonable success, but in lack of evidence as to exactly how much the yield of potatoes on the different plots was increased thereby, the results are not judged to be absolutely reliable, and hence are not published.

The following are the names and addresses of the persons who co-operated with the Station in this line of experimenting during the past year.

M. H. DEAN,	Falls Village.
R. S. HINMAN,	Oxford (P. O. Stevenson).
A. C. BLAKE,	New Britain.
T. A. KIRKHAM,	Newington.
J. E. & H. DANIELS,	Middletown.
K. B. LOOMIS,	South Manchester.
E. H. LATHROP,	Vernon Centre.
J. H. TUCKER,	Lebanon.
J. B. PERRY,	Clark's Falls.
FRANK DAY,	Danielsonville.
W. I. BARTHOLOMEW,	Pomfret (P. O. Putnam).
L. H. HEALEY.	North Woodstock.

The more important details of the experiments, such as the laying out of plots, application of the fertilizers, weighing and harvesting crop, have been done, wherever practicable, under the direct supervision of the Vice-Director or his assistant.

The chief difficulties with field experiments are found in the variations in the soil of a single field. Slight differences in slope, texture, supply of ground water, residues from previous manuring, or other factors of fertility, which at the beginning of the season cannot be observed, often cause serious variations in produce. Deductions made from a single season's results are often very unreliable. It is much safer to repeat the experiment year after year with the same fertilizers on the same plots. If the same peculiarities present themselves during two or three years, the deductions made carry much additional weight.

In connection with nearly all of these experiments, rainfall records have been kept during the growing season. These, as a rule, have been made in close proximity to the experimental fields. The importance of records near at hand is shown by the differences in rainfall between places but a few miles apart.

In another part of the Report, pp. 83–86 will be found the meteorological summary, and the rainfall for the growing seasons, as observed in twenty localities in the State. The precipitation was excessive during the summer months, and the season unfavorable for most crops, especially for corn and potatoes.

MOISTURE TESTS OF CORN.

Pounds required for a Bushel of Dry Shelled Corn.—Since the percentages of water in the produce are variable and the gross weight is not an exact measure of the nutritive material, it is desirable to know the amounts of water in both corn and stover. From most of the experiments large samples of sound ears (good), and of soft ears and nubbins (poor), were secured at harvest, for determination of moisture. These were partially dried, either in a warm room or an open shed, where they were free from the ravages of vermin. At the end of six weeks the samples were reweighed, shelled, and the proportion of cob and shelled corn obtained. Quart samples of the grain were then sealed in glass jars, and sent to the laboratory where complete moisture determinations were made.

With the water-free substance (dry matter) known, the corn could be easily calculated to a uniform water basis. The average amount of water in commercial flint corn is found to be about 11 per cent.* In giving the yields per acre all of our results are reported on this basis.

TABLE 19.

Percentages of Dry Matter of Corn in Ears (Grain and Cob), and the number of Pounds of Ears required for a Bushel of Shelled Corn.

NAME AND LOCALITY.		Water-free corn in sample.	Partially dry corn in sample. (11 % water.)	Pounds of ears at harvest to equal 56 lbs. shelled corn with 11 % water.
		%	%	
M. H. Dean, Falls Village, -	Good, -	59.76	67.2	83.4
	Poor, -	52.60	59.1	94.8
R. S. Hinman, Oxford, - -	Good, -	65.71	73.8	75.9
	Poor, -	59.11	66.4	84.3
The Station, Mansfield, - -	Good, -	55.18	62.0	90.3
	Poor, -	44.07	49.5	113.1
J. H. Tucker, Lebanon, -	Good, -	60.00	67.4	83.1
	Poor, -	43.60	49.0	114.3
E. H. Lathrop, Vernon Centre,	Good, -	58.18	65.4	85.7
	Poor, -	47.36	53.2	105.2
K. B. Loomis, So. Manchester,	Good, -	56.09	63.0	88.9

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*Annual Report of the Connecticut Agricultural Experiment Station, 1888.

TABLE 20.

Percentage of Dry Matter in Corn and Stover from Plots receiving Different Fertilizers.

KIND OF FERTILIZER.	M. H. DEAN, Falls Village—Special Nitrogen Experiment.			E. H. LATHROP, Vernon Centre—Special Nitrogen Experiment.			A. C. BLAKE, New Britain—Soil Test.		
	No. of plot	Corn.	Stover.	No. of plot	Corn.	Stover.	No. of plot	Corn.	Stover.
		%	%		%	%		%	%
Nothing,	0,00	54.15	55.16	0,00	49.45	55.99	0,00	62.23	61.29
Nitrate of soda,	1	49.33	50.24	——	——	——	A.	62.30	60.37
Dissolved bone-black,	2	49.78	52.56	2	52.69	61.80	B.	61.43	61.36
Muriate of potash,	3	53.87	51.11	3	49.39	51.97	C.	59.96	54.14
Nitrate of soda, Dissolved bone-black,	4	51.98	47.77	——	——	——	D.	63.05	60.94
Nitrate of soda, Muriate of potash,	5	54.27	50.23	——	——	——	E.	62.52	60.77
Mixed minerals, as No. 6, Nitrate of soda, one-third ration,	7	56.57	47.04	7	52.71	60.50	F.	61.21	53.57
Mixed minerals, as No. 6, Nitrate of soda, two-thirds ration,	8	56.96	53.26	8	51.08	59.91	——	——	——
Mixed minerals, as No. 6, Nitrate of soda, full ration,	9	56.58	45.59	9	51.82	54.98	——	——	——
Mixed minerals, as No. 6, Sulphate of ammonia, one-third ration,	10	55.96	44.82	10	51.00	52.73	——	——	——
Mixed minerals, as No. 6, Sulphate of ammonia, two-thirds ration,	11	55.48	44.39	11	53.01	52.09	——	——	——
Mixed minerals, as No. 6, Sulphate of ammonia, full ration,	12	56.12	49.63	12	54.83	50.25	——	——	——
Mixed minerals, as No. 6, Dried blood, one-third ration,	13	55.70	42.56	13	54.46	54.92	——	——	——
Mixed minerals, as No. 6, Dried blood, two-thirds ration,	14	56.16	44.22	14	52.26	53.31	——	——	——
Mixed minerals, as No. 6, Dried blood, full ration,	15	55.30	45.80	15	52.30	59.01	——	——	——
Dissolved bone-black, Muriate of potash, mixed minerals,	6, *a*, *b*, *c*,	56.10	45.43	6, *a*, *b*, *c*,	50.36	47.17	G.	63.10	57.23
Plaster,	——	——	——	——	——	——	H.	64.14	66.49

As may be seen in Table 19 (p. 89), the percentages of water-free corn, in the ears at time of harvest, vary greatly. The error involved in taking a uniform weight of ears for all fields to represent a bushel of dry shelled corn is clearly shown. In these experiments, a range of 14 pounds is found in the amount of good corn required for a bushel from different fields, and in the case of poor corn 30 pounds. It is a common practice to consider 80 pounds of ears in the fall sufficient to produce one bushel of shelled corn. In the six analyses made, the maximum quantity of good ears required for a bushel of shelled corn, with 11 per cent. water, was 90 pounds, and the minimum amount 75.8 pounds, while with the poor or soft corn the extremes were 114 and 84 pounds.

In other experiments the percentages of water-free substance (dry matter) of corn and stover were estimated by analysis of crops from each plot. The results are given in Table 20.

In Mr. Dean's experiment a range of only 5 per cent. is found in the dry matter of corn on the different plots. In the case of the stover much greater differences are observed. Omitting the "nothing" (unfertilized) plots, which, owing to the very light yields, were exceptionally dry at harvest, we find an extreme difference of 10.7 per cent. The same peculiarities are seen in the other experiments. There is but little difference to be found in the dry matter of corn, while the stover varies considerably.

The corn on Mr. Dean's field has responded with marked uniformity to applications of potash, paying very little heed to phosphoric acid or nitrogen. The percentage of dry matter seems to be likewise increased by potash. Plots 3 and 5, both of which had potash, give a slight increase of dry matter in corn, over plots 1, 2, and 4, to which no potash was applied. This increase is probably due to the fact that the ears on plot 3 were quite large and well matured, while there was very little fully developed corn where potash was withheld.

The directions for the experiments were published in the last Annual Report and in Bulletin No. 1 of the Station and its supplement. These can be furnished to any one desiring them.

SOIL TEST EXPERIMENTS.

Experiments of this class may be said to have for their object the analysis of the soil by the living plant. The growing plant sends its roots in every direction through the soil. If the essential ingredients of plant food are present in an available form and other conditions, *e. g.*, moisture, temperature, etc., are favorable, the plant will find them and thrive. If any are lacking, the results in the crop at harvest will reveal the deficiencies. By this means we learn whether a soil specially needs phosphoric acid, potash, or nitrogen, and in what form and combination they can be most economically supplied. It is by such study of the soil, its needs and capabilities, by the study of the feeding capacities of plants, and the chemical composition of the resulting crops that we approximate towards a rational and economical use of fertilizers.

It is coming to be quite generally appreciated that plants differ widely in their possession of the special power by which they are enabled to gather their food supply from natural sources and to which the term "feeding capacity" has been applied. Economy in the use of artificial fertilizers also requires that in addition to this the special characteristics and features of different soils be considered.

The wide variations of soils furnish one of the strongest arguments in favor of "home-mixed" fertilizers. The manufacturer who prepares his goods for widespread use cannot take this into consideration; but every farmer can study the peculiarities of his soil and then apply fertilizers to meet its needs.

The following explanation of this class of experiments is taken from the last Annual Report of the Station:

"Chemical analysis is at best a tedious, costly, and, in the present condition of our knowledge, unsatisfactory means for determining the deficiencies of different soils and the economical ways of supplying them. Experiments in which plants are grown in small portions of soil in pots or boxes, have much in their favor, but for the farmer to test his own land, and as a means for the study of the most profitable ways of fertilizing a soil of a given kind, the method of applying different fertilizing materials to different plots of fields on which crops are grown, is found, by long experience, to be, on the whole, decidedly advantageous.

Experience in the field, explained by experiments in the laboratory, has clearly demonstrated that:

1. Soils vary greatly in their capabilities of supplying food to crops. Different ingredients are deficient in different soils.

2. Plants differ widely with respect to their capacities for gathering their food from soil and air. Hence the proper fertilizer

in a given case depends upon the crop as well as upon the soil.

3. The chief use of fertilizers is to supply the plant-food which crops need and soils fail to furnish.

4. The only ingredients of plant food which we need to consider in fertilizers are potash, lime, magnesia, phosphoric acid, sulphuric acid, and nitrogen. Of this list the magnesia is commonly, though not always, supplied in sufficient quantities in even "worn-out" soils. Sometimes its presence in fertilizers may be of considerable importance to crops. Sulphuric acid and lime are more often deficient, and hence one reason of the good effect so often observed from the application of lime and plaster. The remaining substances, the *phosphoric acid*, *potash*, and *nitrogen*, are the most important ingredients of our common commercial fertilizers, because of both their scarcity in the soil and their high cost. It is in supplying these that phosphates, bone manures, potash salts, guano, nitrate of soda, and most other commercial fertilizers are chiefly useful.

5. It is not good economy to pay high prices for materials which the soil may itself furnish, but it is good economy to supply the lacking ones in the cheapest way.

6. The only way to learn what materials are proper in a given case is by observation and experiment. The rational method for determining what ingredients of plant-food a soil fails to furnish in abundance, and how these lacking materials can be most economically supplied, is to put the question to the soil with different fertilizing materials and get the reply in the crops produced.

7. The results of any given experiment are, in the main, applicable only to the particular case where it is made.

8. A single season's experimenting does not tell the whole story. To get complete results the trial must be carried through a series of years and crops."

The fertilizing materials were supplied by the Station, being furnished in standard commercial forms, such as nitrate of soda, dissolved bone-black, muriate of potash, and sulphate of lime. They were mixed under the supervision of the Assistant in Farm Experiments a short time before being needed for use.

The plan of the experiments for soil tests consists in applying on parallel plots of land, fertilizers containing nitrogen, phosphoric acid, and potash, singly, two by two, and all three together. The arrangement of the experiment, the kinds and quantities of the materials used and the valuable ingredients contained in them, are shown in the plan of the field which follows:

SOIL TEST EXPERIMENT.

PLAN OF EXPERIMENTAL FIELD.

Each plot one-tenth acre. Unmanured strips separate the plots. The weight of fertilizers and their valuable ingredients are given in *pounds per acre*.

PLOT O.	Nothing.			
PLOT A.	Nitrate of Soda,	160 lbs.	Nitrogen,	25 lbs.
PLOT B.	Dissolved bone-black,	320 lbs.	Phosphoric Acid,	50 lbs.
PLOT C.	Muriate of Potash,	160 lbs.	Potash,	83 lbs.
PLOT D.	Nitrate of Soda,	160 lbs.	Nitrogen,	25 lbs.
	Dissolved bone-black,	320 lbs.	Phosphoric Acid,	50 lbs.
PLOT E.	Nitrate of Soda,	160 lbs.	Nitrogen,	25 lbs.
	Muriate of Potash,	160 lbs.	Potash,	83 lbs.
PLOT F.	Dissolved bone-black,	320 lbs.	Phosphoric Acid,	50 lbs.
	Muriate of Potash,	160 lbs.	Potash,	83 lbs.
PLOT G.	Nitrate of Soda,	160 lbs.	Nitrogen,	25 lbs.
	Dissolved bone-black,	320 lbs.	Phosphoric Acid,	50 lbs.
	Muriate of Potash,	160 lbs.	Potash,	83 lbs.
PLOT H.	Plaster,	400 lbs.		
PLOT OO.	Nothing.			

DETAILS AND RESULTS OF THE SOIL TEST EXPERIMENTS.

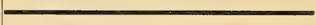
Experiments of this class, successful enough to warrant publication, have been carried out in Lime Rock, Oxford, New Britain, South Manchester, Lebanon, Danielsonville and North Woodstock.

On the following pages, the comparative yields are shown by means of diagrams. The fertilizers are given at the left of the diagram. The length of the line represents the comparative yield per acre of shelled corn from the different plots. The figures given in the last column show the number of bushels of shelled corn per acre.

At the close of this article will be found a series of tabulations giving the results in detail. In all cases the yield of shelled corn per acre is reported on the basis of 11 per cent water; and the stover on the basis of field weights.

SOIL TEST WITH FERTILIZERS ON CORN.

By M. H. DEAN, Lime Rock.

Plot.	Fertilizers.		Yield Shelled Corn Per Acre. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
O.	Nothing, - -	—		9.9
A.	Nitrate of Soda, -	160		16.9
B.	Dis. bone-black, -	320		9.1
C.	Muriate of Potash,	160		18.8
D.	Nitrate of Soda, - Dis. bone-black, -	160 320		18.0
OO.	Nothing, - -	—		14.7
E.	Nitrate of Soda, - Muriate of Potash,	160 160		25.3
F.	Dis. bone-black, - Muriate of Potash,	320 160		17.4
G.	Nitrate of Soda, - Dis. bone-black, - Muriate of Potash,	160 320 160		22.1
H.	Plaster, - -	400		14.8

The field of this experiment is located in the Housatonic Valley. The soil is a light loam with very little vegetable matter, and is apparently worn down by previous cropping without manure. The yield in all cases was light, due in part to the worn out condition of the soil and in part to the unfavorable season. Inequalities of soil have modified the results somewhat, but not enough to destroy their value.

An inspection of the diagram shows that potash gave the most marked results; that nitrogen increased the yield somewhat, and that phosphoric acid had little or no effect. The largest yield was on plot E, where both nitrate and potash were used. That the yield on this plot was larger than that on plot G is probably due to inequalities in the soil.

SOIL TEST WITH FERTILIZERS ON CORN.

By R. S. HINMAN, Oxford.

(P. O. Stevenson.)

Plot.	Fertilizers.		Yield Shelled Corn Per Acre. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
A.	Nitrate of Soda,	160		12.2
B.	Dis. bone-black,	320		17.4
C.	Muriate of Potash,	160		22.5
D.	Nitrate of Soda, Dis. bone-black,	160 320		15.8
E.	Nitrate of Soda, Muriate of Potash,	160 160		33.3
O.	Nothing,	—		12.5
F.	Dis. bone-black, Muriate of Potash,	320 160		32.0
G.	Nitrate of Soda, Dis. bone-black, Muriate of Potash,	160 320 160		37.1
H.	Plaster,	400		14.1
I.	Complete Fert'zer Varied Forms,	600		31.1

Mr. Hinman's farm is located on the Housatonic River, and extends from the valley into the high ground alongside. The soil chosen for the experiment is a river terrace formation, and the field is the same one used for a similar experiment in 1888. The order of plots and the kind of fertilizers, also remain as for that year.

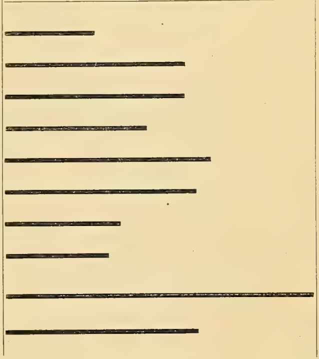
The results in 1888 were not decisive. The crop was evidently supplied from accumulated stores of plant-food in the soil. Much of this, probably, came from the heavy sod plowed under.

This year the results are more conclusive, the most marked effect coming from the use of potash-salts. In every case where potash was omitted, there was a marked falling off in the yield of grain, and the stalks were small and slender.

The average gain from the use of potash is three times that resulting from the use of phosporic acid, and five times that from nitrogen. Potash was plainly the "regulating ingredient" in the experiment.

SOIL TEST WITH FERTILIZERS ON CORN.

By ARTHUR C. BLAKE, New Britain.



Plot.	Fertilizers.		Yield Shelled Corn Per Acre. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
O.	Nothing, - -	160		4.2
A.	Nitrate of Soda, -	320		9.0
B.	Dis. bone-black, -	160		8.9
C.	Muriate of Potash,	160		7.2
D.	Nitrate of Soda, - Dis. bone-black, -	160 320		10.4
E.	Nitrate of Soda, - Muriate of Potash,	160 160		9.3
F.	Dis. bone-black, - Muriate of Potash,	320 160		6.1
OO.	Nothing, - -	—		5.2
G.	Nitrate of Soda, - Dis. bone-black, - Muriate of Potash,	160 320 160		15.2
H.	Plaster, - -	400		9.8

The field selected for this experiment slopes gently to the eastward. The soil is a medium compact loam with a porous subsoil. Its fertility appears to be pretty well reduced. No stable manure has been applied since 1883, although commercial fertilizers have been added in small quantities.

The field is the same one used for a similar experiment in 1888; the kinds of fertilizer and the order of plots remaining the same.

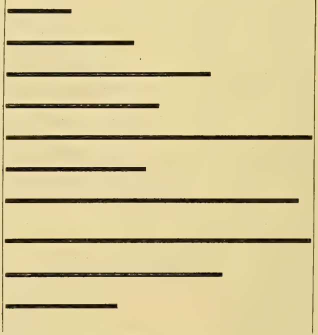
The results show a marked deficiency in all three of the essential ingredients. Potash, however, appears to be less needed than phosphoric acid and nitrogen. The yield from potash alone is less than from nitrogen or phosphoric acid, (plots E and F), and combination of either of these with potash is not as effective as a combination of nitrogen and phosphoric acid (plot D).

In 1888, the nitrate of soda brought an exceptional increase over either of the other ingredients. This peculiarity does not show itself to so marked a degree this year.

The good effect obtained from the use of plaster is worthy of notice.

SOIL TEST WITH FERTILIZERS ON CORN.

By K. B. LOOMIS, South Manchester.

Plot.	Fertilizers.		Yield Shelled Corn Per Acre. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
O.	Nothing, - -	—		9.4
A.	Nitrate of Soda, -	160		17.1
B.	Dis. bone-black, -	320		28.2
C.	Muriate of Potash,	160		21.9
D.	Nitrate of Soda, - Dis. bone-black, -	160 320		41.1
E.	Nitrate of Soda, - Muriate of Potash,	160 160		19.2
F.	Dis. bone-black, - Muriate of Potash,	320 160		39.5
G.	Nitrate of Soda, - Dis. bone-black, - Muriate of Potash,	160 320 160		41.6
H.	Plaster, - -	400		30.2
OO.	Nothing, - -	—		15.6

Mr. Loomis' experiment was conducted on a worn out meadow. It had been in grass for about four years, and produced in 1888 about three-fourths of a ton of hay per acre. The soil is a rather compact loam. Subsoil is compact, with reddish hardpan at three to four feet in depth.

Where the ingredients were used singly, the most marked effect came from the use of phosphoric acid ; and in all of the combinations where phosphoric acid was omitted, there was a marked falling off in the yield.

Plot E, with a liberal quantity of nitrogen and potash, gives a very poor crop, yet when either of these were combined with phosphoric acid, a good yield was secured.

The yield of corn from plots supplied with phosphoric acid averages three and one-half times that from use of potash, and nearly five times that from use of nitrogen. It is evident that phosphoric acid was the regulating ingredient. When the field was visited early in August, the good effect of phosphoric acid was very apparent. In every case where it was used, the color was darker, the growth of stalks heavier, and the general appearance of the crop far superior to that on the plots where it was omitted. A part of the benefit arising from the use of bone-black may be due to the sulphate of lime, for we find a marked increase in yield on the plaster plot (H). That portion of the field was, however, naturally more fertile, as will be seen by a comparison of the nothing plots.

SOIL TEST WITH FERTILIZERS ON CORN.

By J. H. TUCKER, Lebanon.

Plot.	Fertilizers.		Yield Shelled Corn Per Acre. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
A.	Nitrate of Soda, -	160		12.1
B.	Dis. bone-black, -	320		20.9
C.	Muriate of Potash,	160		13.0
O.	Nothing. - -	—		8.8
D.	Nitrate of Soda, - Dis. bone-black, -	160 320		22.1
E.	Nitrate of Soda, - Muriate of Potash,	160 160		12.0
F.	Dis. bone-black, - Muriate of Potash,	320 160		20.2
G.	Nitrate of Soda, Dis. bone-black, Muriate of Potash,	160 320 160		20.3
H.	Plaster, - -	400		8.1

Mr. Tucker's field is part of an old meadow that had been in grass for four years, without the addition of manure. The yield of hay for the previous two years was about one-half ton per acre. The land slopes gently toward the south, but plots F, G, and H, were sufficiently level to allow water to remain during the wet weather of the past season. The soil is a clay loam with much vegetable matter. The subsoil is clay, becoming compact and almost impervious at about two feet in depth.

The yield in all cases was light, but the comparative results are instructive. The very wet weather, late in July and early in August, must have checked the growth considerably on all of the plots, especially on plots F, G, and H.

Phosphoric acid gives marked results wherever used. In the case of plots having only the single ingredients, that with phosphoric acid gives nearly double the yield obtained on either of the other plots. In the case of combinations the yield was also regulated by the phosphoric acid, for wherever it was omitted the crop was but little better than on the nothing plots. Potash, nitrogen and plaster produced little or no effect. Potash gave an average increase over nothing of four-tenths, and nitrogen nine-tenths of a bushel of shelled corn.

When the field was visited in the early part of August, the beneficial effects of phosphoric acid were marked. The growth was two or three times as heavy, the color darker green, and the crop more advanced, wherever this ingredient was used.

One incidental feature in connection with the experiment is worthy of notice as illustrating one cause of inequalities in soils. A nothing plot was placed before A and came next to the south side of a stone wall. It appears that in years past sheep were pastured on the lot during the late fall, and were in the habit of spending the nights in the shelter of this wall. The land there was supplied with much valuable manure and its lasting effects were very apparent. This plot is omitted, as the results obtained do not indicate the natural fertility of the land.

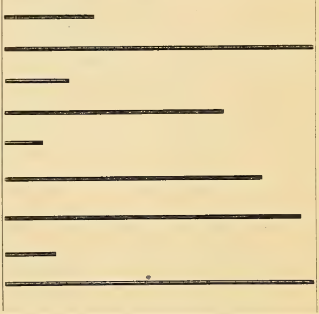
The field selected by Mr. Healey for his soil test (see table top of next page) had been in grass for eleven years previous to 1888, and produced from one-half to three-fourths of a ton per acre during the latter part of that period. The soil is a dark-colored clay loam, with a compact clay subsoil. The field is nearly level and somewhat wet in moist seasons.

A soil test was begun on this field in 1888, but the results were not published, as there was a poor stand of corn on several

SOIL TEST WITH FERTILIZERS ON CORN.

By L. H. HEALEY, North Woodstock.

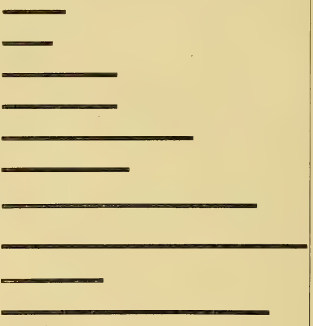
Plot.	Fertilizers.		Yield Shelled Corn Per Acre. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
A.	Nitrate of Soda, -	160		5.8
B.	Dis. bone-black, -	320		20.3
C.	Muriate of Potash,	160		4.1
D.	Nitrate of Soda, - Dis. bone-black, -	160 320		14.5
E.	Nitrate of Soda, - Muriate of Potash,	160 160		2.8
F.	Dis. bone-black, - Muriate of Potash,	320 160		16.8
G.	Nitrate of Soda, - Dis. bone-black, - Muriate of Potash,	160 320 160		19.0
O.	No Manure, - -	—		3.7
I.	Complete Fert'zr, Varied Forms,	600		20.1



plots. The beneficial effects of phosphoric acid were quite noticeable, however. In 1889 the test was repeated, the order of plots and the kinds of fertilizer remaining the same. The total crop secured was small, owing in a great measure to the wet season. Most striking results were obtained from the use of phosphoric acid. The largest yield of grain was secured when this ingredient was applied singly. Potash or nitrogen, whether used alone or together, or in combination with phosphoric acid, appeared to have no beneficial effect. Mr. Healey says that the whole field has been treated alike for about thirty years, and the question naturally arises, was the potash and nitrogen an injury to the crop? When these two ingredients are combined the produce is less than where each is used separately. Compare plot E with plots C and A. When either one is used with bone-black the yield is less than with the bone-black alone. Muriate of potash has not infrequently been found injurious when concentrated near the seed and in dry seasons, but why 160 pounds of muriate spread broadcast in so wet a season as the last should have an injurious effect it is difficult to see.

SOIL TEST WITH FERTILIZERS ON CORN.

By FRANK DAY, Danielsonville.

Plot.	Fertilizers.		Yield Shelled Corn Per Acre. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
o.	Nothing,	—		6.8
A.	Nitrate of Soda,	160		6.0
B.	Dis. bone-black,	320		13.2
C.	Muriate of Potash,	160		13.7
D.	Nitrate of Soda, Dis. bone-black,	160 320		21.7
E.	Nitrate of Soda, Muriate of Potash,	160 160		15.0
F.	Dis. bone-black, Muriate of Potash,	320 160		30.1
G.	Nitrate of Soda, Dis. bone-black, Muriate of Potash,	160 320 160		35.2
H.	Plaster,	400		12.8
I.	Complete Fert'zr, Varied Forms,	600		31.0

Mr. Day's experiment is a repetition of that of 1888 on the same field and with the same arrangement of plots. The soil is a light, alluvial loam; subsoil very similar to the surface, but with small amount of vegetable matter.

The results obtained in 1888 seemed to show a deficiency of all of the essential ingredients. Where single fertilizer compounds were applied potash had the most marked effect, but in the combinations phosphoric acid exerted the greater influence. The largest yields were obtained where complete mixtures were used.

The results of the second year's (1889) test tend to corroborate those of the year before. Phosphoric acid exerted the most marked influence. The best results, however, were again obtained where complete fertilizers were applied. The soil responds readily to commercial fertilizers, and the distance of the field from the farm buildings renders their use economical. The field was over a mile away, and Mr. Day estimated in 1888 that the cost of hauling and applying a liberal amount of manure would have nearly or quite equaled the cost of the fertilizer giving the best yield.

SPECIAL NITROGEN EXPERIMENTS.

The farmers of Connecticut pay out annually about $500,000 for commercial fertilizers. A large part of this sum goes for nitrogen, which costs from eight or ten cents in hair, and horn shavings, to sixteen or seventeen cents in nitrate of soda, sulphate of ammonia and dried blood. The question naturally arises, what is the best and most economical form in which it can be supplied to crops?

A clear distinction should be kept in mind between the commercial value and the agricultural value of a fertilizer. The agricultural value must be measured almost wholly by the increase in the quantity and quality of the crop, and depends in a great measure upon the adaptability of the fertilizer to the crop, to the particular soil to which it is applied, to the season, and to conditions which in no two cases are likely to be the same.

Plants differ widely in their peculiar powers of gathering food from natural sources. Certain crops give very little response to a supply of nitrogen. Corn fails to respond to applications of nitrogen in anything proportionate to the amount supplied, even though this does not exceed that taken up by the crop.

The amount and value of the fertilizer left after the first year, varies greatly with the soil and the fertilizer. Serious losses of nitrogen occur through leaching and chemical changes. Nearly all soils, and especially those of a porous texture, allow much nitrogen to pass through them and escape in the drainage. Losses of this kind are greatest in quick acting fertilizers, as nitrate of soda and sulphate of ammonia. Nearly all soils retain their mineral constituents quite completely, as very little phosphoric acid or potash escapes in the drainage. The question of how to apply nitrogen rationally and economically, becomes one of vast importance to the farmer.

The work of determining how different plants secure their nitrogen, and to what extent certain ones may take it from the air, must be left to the chemist and botanist. These investigations can best be conducted in the laboratory, and by means of pot and box experiments, though the practical applications of the results obtained in this way can best be demonstrated by field experiments. The results of some experiments of this kind undertaken by the Station were published in Bulletin No. 5, and are given more in detail in this Report, pp. 11–51.

The specific problems to be studied in the experiments here referred to are the same as in 1888, and may be stated as follows:

1. How do the plants experimented with get on with the "mineral" fertilizers, such as are supplied by superphosphates and potash salts?

2. More especially, how do they respond to nitrogen when added, in different forms and amounts, to the mineral fertilizers?

3. And finally, what inferences may we draw as to the feeding capacities of the plants, their power to gather their food from soil and air, and the effects of different materials upon their growth, especial reference being made to the nitrogen supply?

The idea is to use the mineral fertilizers, bone-black, and potash salt (which are here called "mixed minerals," and supply all of the ingredients of a "complete fertilizer" except nitrogen), as a basis of comparison, and to compare the produce from this mixture with that obtained when nitrogenous materials are added to it; the increased yield in the latter cases being attributed to the nitrogen. The following quotations are from descriptions and directions prepared for the experiments:

"*The Object* of this experiment is to test the effects of nitrogenous fertilizers in different amounts and combinations upon the growth of the plant, and inferentially its capacity to gather its nitrogen from natural sources."

"*The Fertilizers.*—The ingredients and amounts are such as are used in ordinary practice: Phosphoric acid and potash being supplied in about the proportions that occur in a corn crop of about fifty bushels; and nitrogen in one-third, two-thirds, and full amount in same crop."

"*Forms of Nitrogen.*—The nitrogen is supplied as nitric acid in nitrate of soda; as ammonia in sulphate of ammonia, and as organic nitrogen in dried blood."

"*Quantities of Nitrogen.*—The nitrogen is applied at the rate of twenty-five pounds per acre in 'one-third ration'; fifty pounds per acre in 'two-thirds ration'; and seventy-five pounds per acre in 'full ration.'"

"*Arrangement of Plots and Fertilizers.*—The ingredients are supplied as:

" Partial Fertilizers,	Group I. Nos. 1–3. Each by itself. Group II. Nos. 4.–6. Two by two.	Thus testing the effects of ingredients separately, and capacity of soil."
" Complete Fertilizers,	Group III. Nos. 7–9. Nitrogen as nitric acid in nitrate of soda. Group IV. Nos. 10–12. Nitrogen as ammonia in sulphate of ammonia. Group V. Nos. 13–15. Nitrogen as organic nitrogen in dried blood.	Nitrogen in one-third, two-thirds, and full ration."

"The schedule provides for twenty plots, of which two are unmanured, and eighteen supplied with the experimental fertilizers. Of the latter, three, Nos. 6a, 6b, and 6c, are duplicates of the 'mixed minerals,' No. 6. This gives four plots of 'mixed minerals,' one on each side of each of the three groups, III., IV., and V., in which latter the effects of nitrogen are to be tested. This duplicating the 'mixed minerals' serves the three-fold purpose of testing the uniformity of the soil, replacing unmanured plots, and showing more accurately the actual effects of the nitrogen."

DETAILS AND RESULTS OF SPECIAL NITROGEN EXPERIMENTS.

Experiments of this class on corn, successful enough to warrant publication, have been carried out at Vernon Center, Falls Village and Mansfield. The plan of the experiments, arrangement of plots and fertilizers used are given in Table 21 that follows. Beyond this table the comparative yields from experiments with corn are shown by means of diagrams. The fertilizers are given at the left of the diagram. The length of the lines represent the comparative yield per acre. The figures in the last column give the number of bushels of shelled corn per acre. At the close of this article will be found a series of tabulations giving the results in detail.

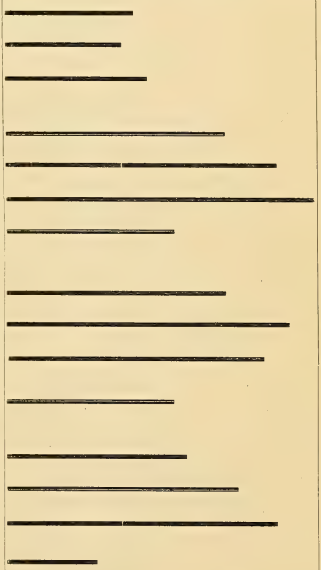
TABLE 21.

Fertilizing Material for Special Nitrogen Experiment.

No. of plot.	KIND.	Amounts per plot.		Amount per acre.	Nitrogen per acre.
		Two-acre set for 1-10 acre plots.	One-acre set for 1-20 acre plots.		
	Preliminary Group—	Lbs.	Lbs.	Lbs.	Lbs.
1.	Nitrate of soda,	16	8	160	25
2.	Dissolved bone-black,	32	16	320	—
3.	Muriate of potash,	16	8	160	—
4.	Nitrate of soda,	16	8	160	25
	Dissolved bone-black,	32	16	320	—
5.	Nitrate of soda,	16	8	160	25
	Muriate of potash,	16	8	160	—
6.	Dissolved bone-black, mixed	32	16	320	—
	Muriate of potash, minerals,	16	8	160	—
	Nitrate of Soda Group—				
7.	Mixed minerals, as No. 6,	48	24	480	—
	Nitrate of soda, one-third ration,	16	8	160	25
8.	Mixed minerals, as No. 6,	48	24	480	—
	Nitrate of soda, two-thirds ration,	32	16	320	50
9.	Mixed minerals, as No. 6,	48	24	480	—
	Nitrate of soda, full ration,	48	24	480	75
6*a*.	Mixed minerals, as No. 6,	48	24	480	—
	Sulphate of Ammonia Group—				
10.	Mixed minerals, as No. 6,	48	24	480	—
	Sulphate of ammonia, 1-third ration,	12	6	120	25
11.	Mixed minerals, as No. 6,	48	24	480	—
	Sulphate of ammonia, 2-thirds ration,	24	12	240	50
12.	Mixed minerals, as No. 6,	48	24	480	—
	Sulphate of ammonia, full ration,	36	18	360	75
6*b*.	Mixed minerals, as No. 6,	48	24	480	—
	Dried Blood Group—				
13.	Mixed minerals, as No. 6,	48	24	480	—
	Dried blood, one-third ration,	16	8	160	25
14.	Mixed minerals, as No. 6,	48	24	480	—
	Dried blood, two-thirds ration,	32	16	320	50
15.	Mixed minerals, as No. 6,	48	24	480	—
	Dried blood, full ration,	48	24	480	75
6*c*.	Mixed minerals, as No. 6,	48	24	480	—

SPECIAL NITROGEN EXPERIMENT ON CORN.

By E. H. LATHROP. Vernon Center.



Plot.	Fertilizers. Kind.	Fertilizers. Lbs. per Acre.	Yield Shelled Corn per Acre. (11 % Water.) Comparative Scale.	Yield Shelled Corn per Acre. (11 % Water.) Bu.
2	Dissolved Bone-black,	320		13.2
3	Muriate of Potash, -	160		12.7
0	Nothing, - - - -	—		13.6
	Nitrate of Soda Group.			
7	Mix'd Minerals, as No. 6, Nit. of Soda, ⅓ ration,	480 160		22.0
8	Mix'd Minerals, as No. 6, Nit. of Soda, ⅔ ration,	480 320		26.6
9	Mix'd Minerals, as No. 6, Nit. of Soda, full ration,	480 480		31.1
6	Dis. Bone-bl'k, } Mixed Mur. of Potash, } Minr'l.	320 160		16.6
	Sulp. of Ammonia Group.			
10	Mix'd Minerals, as No. 6, Sulp. of Am., ⅓ ration,	480 120		22.0
11	Mix'd Minerals, as No. 6, Sulp. of Am., ⅔ ration,	480 240		29.1
12	Mix'd Minerals, as No. 6, Sulp. of Am., full ration,	480 360		25.8
6*a*	Mix'd Minerals, as No. 6,	480		16.3
	Dried Blood Group.			
13	Mix'd Minerals, as No. 6, Dried Blood, ⅓ ration,	480 160		18.0
14	Mix'd Minerals, as No. 6, Dried Blood, ⅔ ration,	480 320		22.8
15	Mix'd Minerals, as No. 6, Dried Blood, full ration,	480 480		27.3
00	Nothing, - - -	—		8.8

The field upon which this experiment was conducted is the one used for a similar purpose in 1888. The order of plots and fertilizers used remained the same as before. Grass had been grown upon the land for the four years previous to 1888, the yield being very light during the latter part of this time.

The largest crops were obtained on the nitrate of soda plots, the yield increasing with the increased quantity of nitrogen. This increase, however, was very slight and far out of proportion to the additional expense. For example plot 9 (full ration) gives an increase of 9.1 bushels of corn and 20 pounds of stover over plot 7 (one-third ration), while the fertilizer on plot 9 cost $8.72 more than that on plot 7.

The yield in all cases was light, and the financial returns indicate a loss. The yield was probably somewhat reduced by the wet weather, but with due allowance for this, very little benefit came from the use of the fertilizers. The results obtained during the two years where no nitrogen (mixed minerals) and the smaller and larger quantities were employed, are shown by the following table :

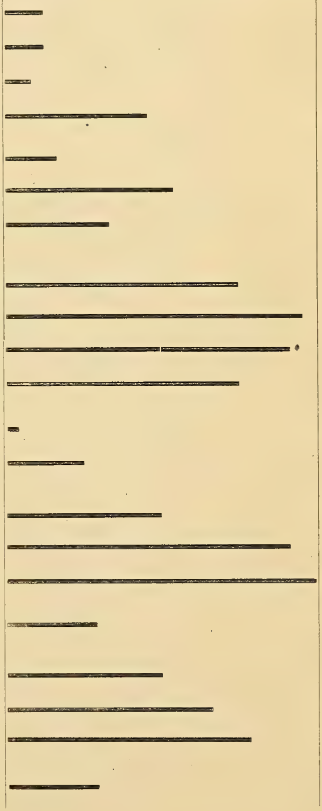
Gain or Loss per Acre from the use of Nitrogen.

PLOTS USED IN OBTAINING AVERAGES.	Increase of Corn over Nothing Plots. Bushels per Acre. 1888.	Increase of Corn over Nothing Plots. Bushels per Acre. 1889.
Plots with mixed minerals, - - - - -	13.2	5.3
Plots with one-third nitrogen ration, - - -	11.4	9.5
Plots with two-thirds nitrogen ration, - - -	12.7	15.0
Plots with full nitrogen ration, - - - -	13.4	16.9

The benefit derived from nitrogen is more apparent the second year, although very little increase comes from the use of large quantities, as will be seen by comparing the two-thirds and full rations. The nitrogen of the soil seems to be slowly exhausted, yet the fact remains that large quantities are nearly always used at a decided loss on corn.

SPECIAL NITROGEN EXPERIMENT ON CORN.

By MYRON H. DEAN, Falls Village.



Plot.	Fertilizers.		Yield Shelled Corn Per Acre. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
0	No Manure,	—		6.1
1	Nitrate of Soda,	160		7.5
2	Dissolved Bone-black,	320		5.2
3	Muriate of Potash,	160		25.3
4	Nitrate of Soda, Dissolved Bone-black,	160 320		10.4
5	Nitrate of Soda, Muriate of Potash,	160 160		30.8
6	Dis. Bone-bl'k, Mixed Mur. of Potash, Minr'l.	320 160		18.3
	Nitrate of Soda Group.			
7	Mix'd Minerals, as No. 6, Nit. of Soda, ⅓ ration,	480 160		42.5
8	Mix'd Minerals, as No. 6, Nit. of Soda, ⅔ ration,	480 320		55.8
9	Mix'd Minerals, as No. 6, Nit. of Soda, full ration,	480 480		52.2
9*a*	Mix'd Minerals, as No. 6, Nit. of Soda, full ration,	480 480		43.0
00	No Manure,	—		3.5
6*a*	Mix'd Minerals, as No. 6,	480		14.4
	Sulp. of Ammonia Group.			
10	Mix'd Minerals, as No 6, Sulp. of Am., ⅓ ration,	480 120		28.4
11	Mix'd Minerals, as No. 6, Sulp. of Am., ⅔ ration,	480 240		51.8
12	Mix'd Minerals, as No. 6, Sulp. of Am., full ration,	480 360		57.0
6*b*	Mix'd Minerals, as No. 6,	480		17.3
	Dried Blood Group.			
13	Mix'd Minerals, as No. 6, Dried Blood, ⅓ ration,	480 160		27.6
14	Mix'd Minerals, as No. 6, Dried Blood, ⅔ ration,	480 320		38.7
15	Mix'd Minerals, as No. 6, Dried Blood, full ration,	480 480		45.3
6*c*	Mix'd Minerals, as No. 6,	480		17.2

Mr. Dean's experiment is a repetition of that of 1888, the field and arrangement of the plots remaining the same. A general description of the land is taken from the last Report, where it is given in Mr. Dean's own words:

"The field selected for my experiment is a smooth and level one, free from stones, and lying on the banks of the Housatonic River. The soil is a light sandy loam, pretty thoroughly exhausted, having been cropped for many years without the application of fertilizers of any kind. It is a very suitable one for experimental work, for on such soil, whatever differences appear may be largely ascribed to the action of the fertilizers, and not to plant food already in the soil."

The field is an outlying portion of the farm, and has been alternated with rye and pasturage in periods of three to four years each, for about twenty years, five to ten bushels of grain and a very light growth of straw being secured from an acre. A light rye stubble, together with a few weeds, was all the vegetable matter turned under when the field was prepared for the first experiment.

The most marked features of the experiment are the heavy increase resulting from the use of potash and the very slight benefit arising from the use of phosphoric acid. After deducting the average yield for the nothing plots, from plots 1, 2, and 3, it is found that potash alone increased the yield eight times over the nitrate of soda plot, and fifty times over the phosphoric acid plot. With corn estimated at 50 cents per bushel and stover at $8.00 per ton, the financial results on these three plots are: From the use of nitrate of soda $1.77 loss; from the use of dissolved bone-black $3.76 loss, and from the muriate of potash $13.17 gain. A still greater loss is, of course, found where phosphoric acid and nitrogen are combined. The increase over nothing, from the use of potash alone, was only 1.4 bushels less for 1889 than for the previous year, on the same plot. This fact leads to the conclusion that the soil has large natural stores of phosphoric acid. Two years' cropping without this ingredient has not apparently reduced the supply.

There is quite a reduction in the yield on the mixed mineral plots as compared with 1888. The effect of nitrogen is more marked than in most experiments of this class. The one-third nitrogen ration, in whatever form used, gave a decided gain over the mixed minerals. The two-thirds ration gave an additional increase, while the full ration gave the heaviest yields in two cases. The yield from the two-thirds ration was the largest, however, in the case of nitrate of soda, while in the case of sulphate of ammonia, and of blood, only a very slight increase resulted from the heavy applications of nitrogen. In the following table is given the increase in yield of corn, resulting from the use of mineral fertilizers; and from the smaller and larger quantities of nitrogen, together with mixed minerals. Also, the cost and value of this increase.

PLOTS USED IN OBTAINING AVERAGES.	1888.			1889.		
	Increase over nothing plots.	*Value of increase.	Cost of fertilizer.	Increase over nothing plots.	*Value of increase.	Cost of fertilizer.
	Bu.			Bu.		
Mixed minerals, - - -	17.5	$15.19	$9.09	12.0	$11.76	$8.00
Same + one-third nitrogen ration,	28.7	24.09	13.03	28.0	24.31	12.37
Same + two-thirds " "	33.7	30.17	16.97	44.0	34.97	16.76
Same + full " "	35.2	32.57	20.91	46.7	36.48	21.14

*Corn at 50 cents per bushel, and stover $8.00 per ton.

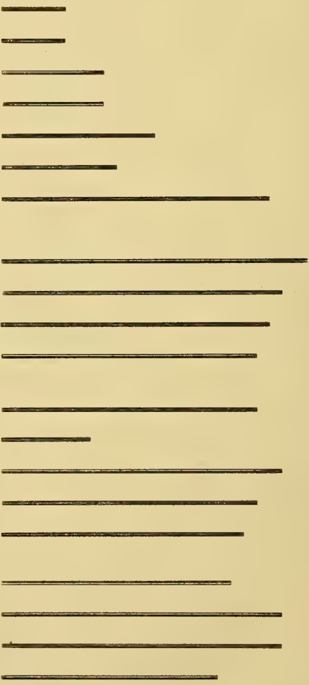
As a part of this experiment, a test has been made of the effect of fertilizer when applied in periods during the growing season, as compared with applications made at one time before planting. Plot 9a has had for two years the same mixture and the same weight as plot 9. The fertilizer on plot 9 was applied all at once before planting, while in the case of 9a the mixture was divided, one-third being applied before planting, one-third about July 1st, and one-third about August 1st. The last two applications were worked into the soil by the use of a cultivator. The following were the results for the two years:

	1888.		1889.	
	Corn.	Stover.	Corn.	Stover.
	Bu.	Lbs.	Bu.	Lbs.
Plot 9, full ration, - - -	50.4	5960	52.2	4000
Plot 9a, " " - - -	47.2	5760	43.0	3200

It is probable that the last applications to plot 9a had very little effect.

SPECIAL NITROGEN EXPERIMENT ON CORN.

By the Station, Mansfield.



Plot.	Fertilizers.		Yield Shelled Corn Per Acre. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
0.	No Manure, - - -	—		5.7
1.	Nitrate of Soda, - -	160		5.7
2.	Dissolved Bone-black, -	320		8.9
3.	Muriate of Potash, -	160		8.6
4.	Nitrate of Soda, - - Dissolved Bone-black, -	160 320		12.3
5.	Nitrate of Soda, - - Muriate of Potash, -	160 160		9.4
6.	Dis. Bone-bl'k, Mixed Mur.of Potash, Minr'l.	320 160		21,7
	Nitrate of Soda Group.			
7.	Mix'd Minerals,as No.6, Nit. of Soda, ⅓ ration,	480 160		25.4
8.	Mix'd Minerals,as No.6, Nit. of Soda, ⅔ ration,	480 320		23.2
9.	Mix'd Minerals,as No.6, Nit. of Soda, full ration,	480 480		22.3
6*a*.	Mix'd Minerals,as No.6,	480		21.2
	Sulp. of Ammonia Group.			
10.	Mix'd Minerals,as No.6, Sulp. of Am., ⅓ ration,	480 120		21.2
00.	No Manure, - - -	—		7.0
11.	Mix'd Minerals,as No.6, Sulp. of Am., ⅔ ration,	480 240		23.4
12.	Mix'd Minerals,as No.6, Sulp. of Am., full ration,	480 360		21.4
6*b*.	Mix'd Minerals,as No.6,	480		20.4
	Dried Blood Group.			
13.	Mix'd Minerals,as No.6, Dried Blood, ⅓ ration,	480 160		19.9
14.	Mix'd Minerals,as No.6, Dried Blood, ⅔ ration,	480 320		23.2
15.	Mix'd Minerals,as No.6, Dried Blood, full ration,	480 480		23.2
6*c*.	Mix'd Minerals,as No.6,	480		18.1

This experiment is also a repetition of that of 1888, the field selected and the arrangement of plots remaining the same. Previous to 1888 the field was in grass. The land was pretty thoroughly run out and produced only very light crops of hay. The soil is a light, porous loam, with very little vegetable matter. The subsoil is sandy, becoming gravel at a few feet in depth.

The yields were small in every case, partly due to the poor condition of the land and partly to the very wet season. Very little difference appeared between the different plots having only the single ingredients supplied. The soil is evidently deficient in all three of the valuable constituents, although phosphoric acid and potash gave the most marked results.

The following table shows the increase over the nothing plots from the use of mixed minerals, and from the smaller and larger quantities of nitrogen in addition to these. In all cases the nitrogen was used at a financial loss:

PLOTS USED IN OBTAINING AVERAGES.	Increase over nothing plots.	*Value of increase.	Cost of fertilizer.
	Bushels.		
Mixed minerals, - - -	14.1	$10.71	$8.00
Same + one-third nitrogen ration,	15.9	11.87	12.37
Same + two-thirds " "	17.0	12.13	16.76
Same + full " "	16.0	11.81	21.14

*Corn at 50 cents per bushel and stover $8.00 per ton.

PRACTICAL DEDUCTIONS.

For the field experiments with fertilizers poor soils are selected where practicable. The object of such experiments is not to secure large crops, but to get comparative results from the use of different fertilizers, under conditions otherwise as uniform as possible.

If the soil lacks uniformity, or has an abundance of available plant-food, it will be impossible to judge how much of the growth is due to the plant-food in the fertilizer applied and how much to that previously stored in the soil. Just here is the chief difficulty with field experiments and one that often makes the results very unreliable, unless they are carried through a series of years. It is almost impossible to find a field of one or two acres that is uniform throughout. Soils vary greatly as to the amounts of available plant-food they contain; as to the relative amounts of sand, clay, or humus present; as to fineness of texture, slope, powers of absorbing and retaining heat and moisture; and as to their powers of holding, in an available form, the fertilizing ingredients supplied. The subsoil also exerts a great and varying influence especially in regulating the supply of moisture from ground water.

The results of field experiments are affected in a marked degree by the season as well as the soil. The past season was very unfavorable for these experiments. The potato experiments suffered from the blight, and their value was thus destroyed. The excessive wet weather, also, greatly reduced on many fields the total yield of corn. Thus it will be seen that the most carefully conducted field experiments will be modified by a number of uncontrollable conditions. On the whole, however, the results are encouraging. Most of the soil tests give comparative results that go far toward pointing out the needs of the soils on which they were made. The interest manifested in the work by the farmers of the State is also very gratifying.

In the majority of cases the largest yields were obtained where complete fertilizers were used. As a rule, however, the best financial returns were not secured from such mixtures. One or two of the essential ingredients that seemed to meet the requirements of the particular soil gave much larger profits. In Mr. Dean's experiments, for example, potash gave good returns alone or when mixed with a small amount of nitrogen. Also, with Mr. Hinman's experiments, potash regulated the matter of profit and loss in every case. When we turn to other localities, however, we find very different results. Mr. Loomis, of South Manchester, Mr. Tucker, of Lebanon, and Mr. Healey, of North Woodstock, find that the addition of phosphoric acid assures good crops, while without it the yields are but little if any better than with no manure.

It would, however, be wrong to assume from these results that the other ingredients did no good. They often increased the crop by supplying the substance that was especially lacking in the soil. The increase was, however, not as a rule in proportion to the added cost.

The deduction to be made from such experiments is that the ingredient present in the soil in the smallest quantity should be liberally supplied, while the other forms of plant-food are to be sparingly added, considerable dependence being placed upon the stores already in the soil. Many soils have supplies of potash or of phosphoric acid, that can be drawn upon year by year without materially lessening their fertility. The soil should not be looked upon simply as a passive and inert medium for holding the given amount of plant food supplied until needed by the crop. We can safely depend on most soils to furnish a part of the needed annual supply. Agencies like air, heat, frost and moisture are ever at work, converting the insoluble soil constituents into forms suitable for the use of the plant, and plants and soil are constantly gathering nitrogen from the air.

The most rational method in compounding fertilizers is to consider the requirements of the soil and the feeding capacities of the plants, together with the chemical composition of the crops. As the rocks from which soils are formed vary widely, so must the resulting soil formations vary as widely. Again, our system of farming has been such as to draw differently upon the stores of plant-food in the soil. By growing stock, and disposing of the same or their products, tons of phosphoric acid have been sold off our farms in bone, muscle, milk and cheese. The greater part of this has never been restored. Phosphoric acid is known to be used up in animal growth to a far greater degree than potash. This may in part account for the great lack of phosphoric acid in many New England soils ; however, the principal source of the diminished fertility is the removal of crops and allowing the manure to go to waste, and in consequence making no adequate return to the soil for that which it has supplied the crop.

The following table will be of service in showing the relative importance of phosphoric acid, potash, and nitrogen, on a large number of soils, in the production of corn. Eighty of these tests are from earlier work by the Director in this line of experimenting. The second list includes sixteen tests made by this Station during the past two years. In the third column the results of the two lots are combined. In the last column are given the percentages of cases in which the different ingredients had a regulating influence, *i. e.*, those in which the crops responded uniformly and largely to the ingredient named, and were apparently influenced but little if at all by the others.

Comparative Effects of Phosphoric Acid, Potash, and Nitrogen, in Ninety-six Experiments.

FERTILIZERS AND THE ESSENTIAL INGREDIENT FURNISHED BY EACH.	Eighty Experiments, 1878-81.	Sixteen Experiments, 1888-9.	Total—Ninety-six Experiments.	Percentage of times each ingredient was regulating.
Superphosphate or dissolved bone-black, supplying phosphoric acid (P_2O_5.)				
Regulating ingredient, - - -	27	5	32	33.3
More or less efficient, - - -	35	5	40	
Inefficient, - - - - -	18	6	24	
Total, - - - - -	80	16	96	
Muriate of potash supplying potash(K_2O.)				
Regulating ingredient, - - -	11	4	15	15.6
More or less efficient, - - -	25	7	32	
Inefficient, - - - - -	44	5	49	
Total, - - - - -	80	16	96	
Nitrate of soda, supplying nitrogen.				
Regulating ingredient, - - -	4	2	6	6.3
More or less efficient, - - -	28	5	33	
Inefficient, - - - - -	48	9	57	
Total, - - - - -	80	16	96	

The so-called regulating ingredient is found by estimating the effect of phosphoric acid, potash, or nitrogen, on all of the plots where used. In all of the soil tests, each ingredient is used four different times, and may be said to have four values. Let us study the effect of potash, for example. The increase from muriate of potash over the average of the nothing plots gives one value for potash. A second value is obtained by subtracting the result with nitrate of soda from that with nitrate of soda and muriate of potash. A third value by subtracting the result with dissolved bone-black from that with dissolved bone-black and muriate of potash. And, finally, a fourth value by subtracting the result with nitrate of soda and dissolved bone-black from that secured from the complete mixture.

In the case of the experiments by the Station, when the average of these four cases was four bushels or more above that obtained from either nitrogen or phosphoric acid, the potash was called the regulating ingredient. When potash gave an increase of four bushels or more over nothing, and did not exceed either of the other ingredients by at least four bushels, it was called more or less efficient. When the increase over the nothing plots was less than four bushels, potash was considered inefficient. In the same way the effects of nitrogen and phosphoric acid were obtained. In many cases the different values for potash, phosphoric acid and nitrogen are very regular; in others they are extremely variable; by taking the average of four plots in each test, however, very fair comparisons can be made.

The special nitrogen experiments simply repeat the story of similar experiments, conducted in earlier years, in this and other States. Nitrogen, when used in large quantities, has not paid for itself in the increase of corn. In the experiment at Mansfield, the yield with mixed minerals was only about two bushels less than where 24 pounds of nitrogen was added with the minerals. Where the nitrogen was raised to 48 and 72 pounds, scarcely any additional increase resulted. In Mr. Dean's experiment, the effect of nitrogen was more marked, but even here the full ration gave very little increase over the two-thirds ration.

Many plants readily utilize nitrogen supplied in fertilizers; others, when grown in rotation, get on very well if supplied with small quantities in addition to that of the soil; and still others gather large quantities from the air. From our present knowledge, we must place the corn plant in the second of these classes. Numerous experiments indicate that corn gets along very well, and gives fair returns, when the fertilizers supplied contain one-third to one-half the nitrogen removed by the crop. Only in very rare cases is the increase of corn proportionate to the increase of nitrogen, and the consequent cost of the fertilizer.

In the following table, taken in part from the last Annual Report, are shown the results of earlier experiments in this line by the Director, and the results of the Station's experiments for the past two years. Here are given the average yields on a large number of plots to which phosphoric acid and potash (mixed minerals) were added. With these will be found the results on similar plots having the same mineral fertilizers, but in addition nitrogen equalling approximately, one-third, two-thirds, and the full amount, represented in a crop of corn and stover yielding about fifty bushels per acre :

SPECIAL NITROGEN EXPERIMENTS.	Eighteen Experiments. 1878–81.	Four Experiments 1888.	Three Experiments. 1889.
	Bushels.	Bushels.	Bushels.
Mixed minerals alone,	43.0	33.4	18.2
Same + one-third nitrogen ration,	48.4	38.2	25.2
Same + two-thirds nitrogen ration,	48.8	40.2	32.7
Same + full ration,	49.6	39.2	34.0

In the three experiments of 1889, which are repetitions of those of the previous year, (with the same fertilizers on the same plots), the yields for 1889 are much less than in 1888, and especially so on the plots having no nitrogen. This can hardly be due entirely to differences in season. Both were poor corn years. While the corn plant does not respond by increase of yield to the nitrogen supplied in fertilizers, it does seem to exhaust the soil supply of nitrogen available to corn. One of the perplexing questions is : What becomes of the nitrogen added, and why cannot or does not the plant make use of it ?

Nitrogen holds in plant life and in the economy of the farm, a very different position from phosphoric acid, potash or lime. In the first place, it is the most costly ingredient ; and, secondly, it is the most changeable and uncertain. We pay for it from two to three times as much as either potash or phosphoric acid costs. At the same time it exists in abundance in the air, though for the most part, in the free state, *i. e.*, not combined with other elements. It is supplied to our soils as organic compounds, in dried blood, fish, etc., as salts of ammonia, or in the form of nitrates, but only in the latter form can plants utilize it to any very great extent. The other forms must be partly or entirely changed into nitrates before the plant can make use of them. These changes take place after the fertilizer is added to the soil.

In the transformation of nitrogen compounds in the soil, we do not know how much free nitrogen escapes, but it is probable that there is considerable loss in this way. Again, when the more soluble nitrogen compounds, as nitrate of soda, are added to the soil in large quantities, before the plant is ready to make use of them much nitrogen is washed away through the drainage; the same holds true of organic nitrogen, which, like ammonia, is nitrified, *i. e.*, changed to nitric acid in the soil, and thereby rendered soluble. Especially is this the case with light, porous soils, and with loose, open subsoils.

Some if not all of the legumes gather large quantities of nitrogen from the air and are but little helped by nitrogen in fertilizers; while rye, oats, barley, wheat, the root crops, and potatoes need abundance of it in a readily available form at the disposal of their roots, and respond to nitrogeneous fertilizers.

One of the most perplexing problems in the whole matter of manuring, is the nitrogen supply and how to utilize it. To get nitrogen into the soil, to hold it there until needed by the crop, and then to obtain from it the greatest possible benefit, are questions that perplex the scientist as well as the farmer.

There is little doubt to-day but what one of the cheapest and best ways of adding nitrogen to soils is to grow the "nitrogen collectors," as clover, alfalfa, vetch, lupines, serradella, and peas, and feed them and save the manure, or plow them under. We thus supply nitrogen in large quantities to the "nitrogen feeders," as wheat, oats, rye, root crops, potatoes—and perhaps, corn. Clover, vetch, serradella, and small varieties of peas can be sown in the spring upon grain fields, and as soon as the grain is harvested, they will produce a good crop for plowing under late in the fall or the next spring.

The tables which follow contain the details of the experiments discussed above. They are in substantially the same form as those of the Report of 1888, and probably need no explanation. The "gain or loss over nothing plots" given in the last column of each table is found by subtracting the average yield per acre of the nothing (unmanured) plots from that of the respective plots, as in the case of plot A, Table 22. The average yield of the nothing plots was 12.3 bushels per acre; of the nitrate of soda plot, 16.9 bushels per acre; the gain over the nothing plots is therefore 4.6 bushels.

Table 22.—SOIL TEST WITH FERTILIZERS ON CORN.

By M. H. DEAN, Falls Village.

No. of Plot.	Fertilizer Per Acre.			Yield Per Plot. 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % water		Stover.	Gain (or Loss –) over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
O.	Nothing,	—	—	43	45	147	5.2	4.7	1470	—
A.	Nitrate of Soda,	160	4.20	84	64	189	10.1	6.8	1890	4.6
B.	Dis. Bone-black,	320	4.16	37	45	167	4.4	4.7	1670	-3.2
C.	Muriate of Potash,	160	3.36	115	47	334	13.8	5.0	3340	6.5
D.	Nitrate of Soda, Dis. Bone-black,	160 320	8.84	84	75	277	10.1	7.9	2770	5.7
OO.	Nothing,	—	—	61	70	179	7.3	7.4	1790	—
E.	Nitrate of Soda, Muriate of Potash,	160 160	7.88	160	58	289	19.2	6.1	2890	13.0
F.	Dis. Bone-black, Muriate of Potash,	320 160	8.00	110	40	295	13.2	4.2	2950	5.1
G.	Nitrate of Soda, Dis. Bone-black, Muriate of Potash,	160 320 160	12.36	136	55	305	16.3	5.8	3050	9.8
H.	Plaster,	400	1.20	87	42	208	10.4	4.4	2080	2.5

Table 23.—SOIL TEST WITH FERTILIZERS ON CORN.

By HOWARD R. STEVENS, on Farm of R. S. Hinman, Oxford.

No. of Plot.	Fertilizer Per Acre.			Yield Per Plot. 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % water		Stover.	Gain (or Loss –) over Nothing Plots
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
A.	Nitrate of Soda,	160	4.20	53	44	108	7.0	5.2	1080	–.3
B.	Dis. Bone-black,	320	4.16	102	34	130	13.4	4.0	1300	4.9
C.	Muriate of Potash,	160	3.36	141	33	178	18.6	3.9	1780	10.0
D.	Nitrate of Soda, Dis. Bone-black,	160 320	8.84	94	29	139	12.4	3.4	1390	3.3
E.	Nitrate of Soda, Muriate of Potash,	160 320	7.88	222	35	222	29.2	4.1	2220	20.8
O.	Nothing,	—	—	60	39	139	7.9	4.6	1390	—
F.	Dis. Bone-black, Muriate of Potash,	320 160	8.00	210	36	255	27.7	4.3	2550	19.5
G.	Nitrate of Soda, Dis. Bone-black, Muriate of Potash,	160 320 160	12.36	258	26	217	34.0	3.1	2170	24.6
H.	Plaster,	400	1.20	77	34	148	10.1	4.0	1480	1.6
I.	Complete Fertilizer Various Forms,	600	13.07	210	29	246	27.7	3.4	2460	18.6

TABLE 24.—SOIL TEST WITH FERTILIZERS ON CORN.

BY A. C. BLAKE, NEW BRITAIN.

No. of Plot.	FERTILIZER PER ACRE.			YIELD PER PLOT. 1-10 ACRE.			YIELD PER ACRE.		
	Kind.	Weight.	Cost.	Ears.		Stover.	Total Shelled Corn. 11 % water.	Stover.	Gain over Nothing Plots.
				Good.	Poor.				
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Lbs.	Bu.
O.	Nothing, - -	—	—	25	9	81	4.2	810	—
A.	Nitrate of Soda, -	160	4.20	52	20	106	9.0	1060	4.3
B.	Dis. Bone-black, -	320	4.16	57	15	123	8.9	1230	4.2
C.	Muriate of Potash, -	160	3.36	41	19	129	7.2	1290	2.5
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320	8.84	55	27	125	10.4	1250	5.7
E.	Nitrate of Soda, - Muriate of Potash, -	160 160	7.88	50	24	132	9.3	1320	4.6
F.	Dis. Bone-black, - Muriate of Potash, -	320 160	8.00	39	11	148	6.1	1480	1.4
OO.	Nothing, - -	—	—	24	17	98	5.2	980	—
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash, -	160 320 160	12.36	91	29	174	15.2	1740	10.5
H.	Plaster, - - -	400	1.20	52	24	109	9.8	1090	5.1

TABLE 25.—SOIL TEST WITH FERTILIZERS ON CORN.

BY K. B. LOOMIS, SOUTH MANCHESTER.

No. of Plot.	FERTILIZER PER ACRE.			YIELD PER PLOT. 1-10 ACRE.			YIELD PER ACRE.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % water		Stover.	Gain over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
O.	Nothing, - -	—	—	40	52	133	4.5	4.9	1330	—
A.	Nitrate of Soda, -	160	4.20	90	75	220	10.1	7.0	2200	4.6
B.	Dis. Bone-black, -	320	4.16	187	77	237	21.0	7.2	2370	15.7
C.	Muriate of Potash, -	160	3.36	119	91	246	13.4	8.5	2460	9.4
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320	8.84	325	48	302	36.6	4.5	3020	28.6
E.	Nitrate of Soda, - Muriate of Potash, -	160 160	7.88	114	68	242	12.8	6.4	2420	6.7
F.	Dis. Bone-black, - Muriate of Potash, -	320 160	8.00	313	46	374	35.2	4.3	3740	27.0
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash, -	160 320 160	12.36	327	51	376	36.8	4.8	3760	29.1
H.	Plaster, - - -	400	1.20	195	89	272	21.9	8.3	2720	17.7
OO.	Nothing, - -	—	—	79	72	195	8.9	6.7	1950	—

TABLE 26.—SOIL TEST WITH FERTILIZERS ON CORN.

BY J. H. TUCKER, LEBANON.

No. of Plot.	Fertilizer Per Acre.			Yield Per Plot. 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % water		Stover.	Gain (or Loss -) over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
A.	Nitrate of Soda, -	160	4.20	57	60	125	6.9	5.2	1250	3.3
B.	Dis. Bone-black, -	320	4.16	111	86	157	13.4	7.5	1570	12.1
C.	Muriate of Potash, -	160	3.36	59	67	135	7.1	5.9	1350	4.2
O.	Nothing, - -	—	—	22	71	102	2.6	6.2	1020	—
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320	8.84	128	77	170	15.4	6.7	1700	13.3
E.	Nitrate of Soda, - Muriate of Potash, -	160 160	7.88	51	67	157	6.1	5.9	1570	3.2
F.	Dis. Bone-black, - Muriate of Potash, -	320 160	8.00	114	74	172	13.7	6.5	1720	11.4
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash, -	160 320 160	12.36	116	72	179	14.0	6.3	1790	11.5
H.	Plaster, - - -	400	1.20	27	56	121	3.2	4.9	1210	-.7

TABLE 27.—SOIL TEST WITH FERTILIZERS ON CORN.

BY L. H. HEALEY, NORTH WOODSTOCK.

No. of Plot.	Fertilizer Per Acre.			Yield Per Plot. 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % water		Stover.	Gain (or Loss -) over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
A.	Nitrate of Soda, -	160	4.20	34	20	98	3.9	1.9	980	2.1
B.	Dis. Bone-black, -	320	4.16	166	12	149	19.2	1.1	1490	16.6
C.	Muriate of Potash, -	160	3.36	24	14	75	2.8	1.3	750	.4
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320	8.84	109	20	139	12.6	1.9	1390	10.8
E.	Nitrate of Soda, - Muriate of Potash, -	160 160	7.88	20	5	96	2.3	.5	960	-.9
F.	Dis. Bone-black, - Muriate of Potash, -	320 160	8.00	132	16	174	15.3	1.5	1740	13.1
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash, -	160 320 160	12.36	153	14	219	17.7	1.3	2190	15.3
O.	Nothing, - -	—	—	28	5	84	3.2	.5	840	—
I.	Complete Fertiliz'r, Various Forms,	600	13.07	153	26	120	17.7	2.4	1200	16.4

TABLE 28.

SOIL TEST WITH FERTILIZERS ON CORN.

By FRANK DAY, Danielsonville.

No. of Plot.	Fertilizer Per Acre.			Yield Per Plot. 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % water		Stover.	Gain (or Loss -) over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
O.	Nothing,	—	—	28	39	118	3.2	3.6	1180	—
A.	Nitrate of Soda,	160	4.20	25	33	120	2.9	3.1	1200	-.8
B.	Dis. Bone-black,	320	4.16	105	11	163	12.2	1.0	1630	6.4
C.	Muriate of Potash,	160	3.36	98	25	149	11.4	2.3	1490	6.9
D.	Nitrate of Soda, Dis. Bone-black,	160 320	8.84	160	34	203	18.5	3.2	2030	14.9
E.	Nitrate of Soda, Muriate of Potash,	160 160	7.88	98	39	185	11.4	3.6	1850	8.2
F.	Dis. Bone-black, Muriate of Potash,	320 160	8.00	250	12	319	29.0	1.1	3190	23.3
G.	Nitrate of Soda, Dis. Bone-black, Muriate of Potash,	160 320 160	12.36	283	26	381	32.8	2.4	3810	28.4
H.	Plaster,	400	1.20	90	26	157	10.4	2.4	1570	6.0
I.	Complete Fertiliz'r, Various Forms,	600	13.07	250	21	365	29.0	2.0	3650	24.2

TABLE 29.

SPECIAL NITROGEN EXPERIMENT ON CORN.

By E. H. LATHROP, Vernon Center.

No. of Plot.	Fertilizer Per Acre.			Yield Per Plot. 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % water		Stover.	Gain over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
2.	Dissolved Bone-black, -	320	4.16	69	54	261	8.1	5.1	2610	2.0
3.	Muriate of Potash, - -	160	3.36	47	76	232	5.5	7.2	2320	1.5
0.	Nothing, - - - -	—	—	42	91	198	4.9	8.7	1980	—
	Nitrate of Soda Group.									
7.	Mixed Minerals, as No. 6, Nitrate of Soda, ⅓ ration,	480 160	12.36	105	102	309	12.3	9.7	3090	10.8
8.	Mixed Minerals, as No. 6, Nitrate of Soda, ⅔ ration,	480 320	16.72	128	123	317	14.9	11.7	3170	15.4
9.	Mixed Minerals, as No. 6, Nit. of Soda, full ration,	480 480	21.08	173	115	311	20.2	10.9	3110	19.9
6.	Dis. Bone-blk, Mixed Mu.of Potash, Minr'ls.	320 160	8.00	85	71	320	9.9	6.7	3200	5.4
	Sulp. of Ammonia Group.									
10.	Mixed Minerals, as No. 6, Sulp. of Am., ⅓ ration,	480 120	12.60	114	91	309	13.3	8.7	3090	10.8
11.	Mixed Minerals, as No. 6, Sulp. of Am., ⅔ ration,	480 240	17.24	168	100	313	19.6	9.5	3130	17.9
12.	Mixed Minerals, as No. 6, Sulp. of Am., full ration,	480 360	21.86	126	117	282	14.7	11.1	2820	14.6
6*a*.	Mixed Minerals, as No. 6.	480	8.00	87	64	341	10.2	6.1	3410	5.1
	Dried Blood Group.									
13.	Mixed Minerals, as No. 6, Dried Blood, ⅓ ration,	480 160	12.16	97	70	341	11.3	6.7	3410	6.8
14.	Mixed Minerals, as No. 6, Dried Blood, ⅔ ration,	480 320	16.32	132	78	342	15.4	7.4	3420	11.6
15.	Mixed Minerals, as No. 6, Dried Blood, full ration,	480 480	20.48	167	82	343	19.5	7.8	3430	16 1
00.	Nothing, - - - -	—	—	15	74	202	1.8	7.0	2020	—

TABLE 30.

SPECIAL NITROGEN EXPERIMENT ON CORN.

BY M. H. DEAN, FALLS VILLAGE.

No. of Plot.	Fertilizer Per Acre.			Yield Per Plot. 1–20 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % water		Stover.	Gain over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
0.	Nothing, - - - -	—	—	12	15	57	2.9	3.2	1140	—
1.	Nitrate of Soda, - -	160	4.20	18	15	65	4.3	3.2	1300	2.7
2.	Dissolved Bone-black, -	320	4.16	13	10	54	3.1	2.1	1080	.4
3.	Muriate of Potash, -	160	3.36	95	12	130	22.8	2.5	2600	20.5
4.	Nitrate of Soda, - - Dissolved Bone-black, -	160 320	8.84	30	15	81	7.2	3.2	1620	5.6
5.	Nitrate of Soda, - - Muriate of Potash, -	160 160	7.88	115	15	175	27.6	3.2	3500	26.0
6.	Dis. Bone-bl'k, Mixed Mur.of Potash, Minr'l.	320 160	8.00	65	13	148	15.6	2.7	2960	13.5
	Nitrate of Soda Group.									
7.	Mix'd Minerals,as No.6, Nit. of Soda, ⅓ ration,	480 160	12.36	170	8	182	40.8	1.7	3640	37.7
8.	Mix'd Minerals,as No.6, Nit. of Soda, ⅔ ration,	480 320	16.72	220	14	204	52.8	3.0	4080	51.0
9.	Mix'd Minerals,as No.6, Nit. of Soda, full ration,	480 480	21.08	200	20	200	48.0	4.2	4000	47.4
9*a*.	Mix'd Minerals,as No.6, Nit. of Soda. full ration,	480 480	21.08	158	24	164	37.9	5.1	3280	38.2
00.	Nothing, - - - -	—	—	5	11	46	1.2	2.3	920	—
6*a*.	Mix'd Minerals,as No.6,	480	8.00	41	22	147	9.8	4.6	2940	9.6
	Sulp.of Ammonia Group.									
10.	Mix'd Minerals,as No.6, Sulp. of Am., ⅓ ration,	480 120	12.60	101	20	192	24.2	4.2	3840	23.6
11.	Mix'd Minerals,as No.6, Sulp. of Am., ⅔ ration,	480 240	17.24	200	18	219	48.0	3.8	4380	47.0
12.	Mix'd Minerals,as No.6, Sulp. of Am., full ration,	480 360	21.86	222	18	208	53.2	3.8	4160	52.2
6*b*.	Mix'd Minerals,as No.6,	480	8.00	58	16	145	13.9	3.4	2900	12.5
	Dried Blood Group.									
13.	Mix'd Minerals,as No.6, Dried Blood, ⅓ ration,	480 160	12.16	107	9	167	25.7	1.9	3340	22.8
14.	Mix'd Minerals,as No.6, Dried Blood, ⅔ ration,	480 320	16.32	151	12	218	36.2	2.5	4360	33.9
15.	Mix'd Minerals,as No.6, Dried Blood, full ration,	480 480	20.48	182	8	239	43.6	1.7	4780	40.5
6*c*.	Mix'd Minerals,as No.6,	480	8.00	64	9	154	15.3	1.9	3080	12.4

TABLE 31.

SPECIAL NITROGEN EXPERIMENT ON CORN.

BY THE STATION, MANSFIELD.

No. of Plot.	Fertilizer Per Acre.			Yield Per Plot. 1-20 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % water		Stover.	Gain (or Loss –) over Nothing Plots
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
0.	Nothing,	—	—	7	23	30	1.6	4.1	600	—
1.	Nitrate of Soda,	160	4.20	7	23	30	1.6	4.1	600	–.6
2.	Dissolved Bone-black,	320	4.16	17	29	32	3.8	5.1	640	2.6
3.	Muriate of Potash,	160	3.36	18	26	41	4.0	4.6	820	2.3
4.	Nitrate of Soda, Dissolved Bone-black,	160 320	8.84	33	28	41	7.3	5.0	820	6.0
5.	Nitrate of Soda, Muriate of Potash,	160 160	7.88	20	28	41	4.4	5.0	820	3.1
6.	Dis. Bone-bl'k, Mixed Mur.of Potash, Minr'l.	320 160	8.00	82	20	85	18.2	3.5	1700	15.4
	Nitrate of Soda Group.									
7.	Mix'd Minerals,as No.6, Nit. of Soda, ⅓ ration,	480 160	12.36	96	23	81	21.3	4.1	1620	19.1
8.	Mix'd Minerals,as No.6, Nit. of Soda, ⅔ ration,	480 320	16.72	84	26	76	18.6	4.6	1520	16.9
9.	Mix'd Minerals,as No.6, Nit. of Soda, full ration,	480 480	21.08	84	21	69	18.6	3.7	1380	16.0
6*a*.	Mix'd Minerals,as No.6,	480	8.00	78	22	76	17.3	3.9	1520	14.9
	Sulp.of Ammonia Group.									
10.	Mix'd Minerals,as No 6, Sulp. of Am., ⅓ ration,	480 120	12.60	79	21	83	17.5	3.7	1660	14.9
00.	Nothing,	—	—	11	26	30	2.4	4.6	600	—
11.	Mix'd Minerals,as No.6, Sulp. of Am., ⅔ ration,	480 240	17.24	85	26	75	18.8	4.6	1500	17.1
12.	Mix'd Minerals,as No.6, Sulp. of Am., full ration,	480 360	21.86	76	26	81	16.8	4.6	1620	15.1
6*b*.	Mix'd Minerals,as No.6,	480	8.00	73	24	67	16.2	4.2	1340	14.1
	Dried Blood Group.									
13.	Mix'd Minerals,as No.6, Dried Blood, ⅓ ration,	480 160	12.16	68	27	73	15.1	4.8	1460	13.6
14.	Mix'd Minerals, as No.6, Dried Blood, ⅔ ration,	480 320	16.32	88	21	75	19.5	3.7	1500	16.9
15.	Mix'd Minerals,as No.6, Dried Blood, full ration,	480 480	20.48	89	20	83	19.7	3.5	1660	16.9
6*c*.	Mix'd Minerals,as No.6,	480	8.00	69	16	75	15.3	2.8	1500	11.8

EFFECTS OF DIFFERENT FERTILIZERS UPON THE COMPOSITION OF CORN.

By Charles D. Woods.

In connection with the field experiments with fertilizers reported above it was thought that a study of the proximate composition of the produce grown might be valuable in contributing to the knowledge of:—

(1.) The effects of different fertilizers upon the percentage composition, and upon the total yield of nutritive ingredients of the grain and stover of the maize plant, with especial reference to the effect of nitrogenous fertilizers upon the amounts of protein.

(2.) The range of error in the ordinary method of estimating the effects of the fertilizers by the amount of produce as weighed in the field at harvest. This method assumes uniform moisture content and uniform percentages of nutrients in the produce with the different fertilizers.

(3.) The range of variation in composition that may be expected in grain and stover produced from the same kind of corn when grown upon different soils and with different fertilizers.

Collateral questions, as the ratio of corn to cob and the proportion of albuminoid and non-albuminoid nitrogen, etc., were studied so far as circumstances allowed.

Data of embarrassing amount have accumulated. Full discussion is impossible in the limits of the present Report. We therefore content ourselves with giving, in the tables that follow, the condensed results of the analyses, with a few observations based upon them, and reserve the more detailed discussion for future publication.

THE EXPERIMENTS.

The field experiments upon corn undertaken by the Station in co-operation with farmers in various parts of the State are of three kinds.

(1.) Experiments for soil tests.

(2.) Experiments for testing the effects of different quantities of the same fertilizers.

(3.) Experiments for study of the effects of nitrogen in different quantities and from different kinds of nitrogenous fertilizers, as nitrate of soda, sulphate of ammonia, and dried blood.

The experiments of 1888 were described in the Station Report of that year, pp. 47–94, and those of 1889 in this Report, pp. 87 to 126.

From the experiments of 1888, the corn and stover of one soil test and four special nitrogen experiments, and from the experiments of 1889, the produce of one soil test, (from the same field as that of 1888) and two special nitrogen experiments, (one of which was from the same field as that of 1888), were selected for analysis. Experiments were selected in which the differences in the different plots were especially marked. Accessibility was also a factor in the selection, it being desirable that the samples should reach the Station laboratory as soon as possible after harvesting, in order that weights made in the field might be verified before the samples had opportunity to change their moisture content in any marked degree.

It is to be especially noted that both seasons, 1888 and 1889, were decidedly unfavorable for corn, and that the amounts of produce were very small.

METHOD OF OBTAINING SAMPLES.

The corn was cut and stacked, that of each plot being kept separate, some weeks before the weighing and sampling. In each case a dry day following one or more of sunshine was chosen for weighing, husking and taking samples for analysis. As the stooks on a given plot were opened a representative armful was taken from each and put into a pile. From this pile, a sample, varying from five to twenty pounds, was selected, weighed and husked. After husking, the corn and stover were weighed separately, and the stover was cut into pieces an inch, or thereabouts, in length. From the corn thus obtained and from the thoroughly mixed stover, samples varying from three to ten pounds were selected. These final samples were weighed, placed in cotton bags and immediately shipped to the laboratory. On receipt they were again weighed, thereby checking the field weights. The samples were usually quite green and were placed over a register for two or three days until they were dry enough to remove danger of molding. They were then stored in the upper part of the laboratory until they were analyzed. At the time of analysis the samples were much dryer than they would have been if taken directly from the corn bin or stover loft. In the case of the samples procured in 1889, the corn was removed from the cob immediately after weighing and the corn and cob were weighed separately. When these were analyzed a sample was taken of all the kernels, both "good" and "poor." In 1888, only perfect kernels were used for analysis. Great care was taken that the samples selected should, in each case, represent the plot as fairly as possible. The samples were rather small, but it is to be borne in mind that on the plots which had no manure, or fertilizers that were not adapted to the special cases, the total yield was very small. Nevertheless, larger samples might have been better. The difficulty is that considerable time is required to select the larger samples, weigh, husk, weigh again, cut up the stover, select final samples of corn and stover, weigh and bag each separately. Accuracy requires that the whole of this, for a given experiment, shall be done in one day, after the dew is off in the morning and before it forms at night. The sampling in the field was nearly all done by the Vice-Director of the Station.

METHODS OF ANALYSIS.

The methods of analysis recommended in 1887 by the Association of Official Agricultural Chemists, have been followed in the main. The substance was prepared for analysis by pulverizing and passing it through round holes half a millimeter in diameter. Water was estimated by drying in a water oven from four to six hours in a stream of dry hydrogen at practically 96° C. Fat was estimated by extracting about two grams of the substance with anhydrous ether from eight to twelve hours. Every hour or two during each extraction the ether was allowed to completely drain out of the extraction tube; aside from this the extraction was continuous. Protein was estimated by determining nitrogen by the Kjeldahl method and multiplying the result by 6.25. Albuminoid nitrogen was estimated by Stutzer's, and crude fiber by the Weende method. Ash was estimated by the official method, with the exception that after the evaporation of the aqueous extract the platinum dish was heated to faint redness to expel remaining water, and to burn any organic matter in the extract.

All analyses were made in duplicate, and in case the results did not agree closely, or any sample showed marked difference from the other samples from the same field, the analysis was repeated and the results verified. Variations in duplicate determination of nitrogen of .05%, of fiber of stover of .2%, and of other constituents, of .1%, were considered sufficient to require a repetition of the analysis. Ordinarily the variations of duplicates were much less than these mentioned.

EXPLANATION OF TABLES.

In tables 32, 36, 40, 44, 48, 49, 53 and 57, the proximate analyses (calculated on water-free basis) of the corn and stover from the different plots of the different experiments are given, each table containing the results of analyses of all the samples obtained from one experiment.

In order to reduce the number of samples as much as possible, only one sample was taken for plots that were treated alike; *e. g.*, the portions taken for analysis from the two "nothing" plots were combined in one sample. By reference to the first column (number of plot) the number of plots which the samples represent can be readily determined, *e. g.*, in table 36, Laboratory No. 633, the sample represents the three plots, 7, 10 and 13.

The last column in each of the above enumerated tables contains the percentage of water (moisture) in the stover at the time of harvest, *i. e.*, in the field when the samples were taken. In the samples from the experiments of 1888, the corn was not shelled until the time of analysis, hence its water content at harvest is undetermined. In 1889 the corn was shelled as soon as the samples were received, and in the last column of the "corn" analysis, tables 49, 53 and 57, the percentage of water (moisture) at time of harvest is given.

The percentage of protein was obtained in all cases by multiplying the percentage of nitrogen by 6.25; and the percentage of "nitrogen-free extract" was obtained by difference, *i. e.*, adding the percentages of protein, fat, fiber and ash together and subtracting the sum from 100, the remainder being "nitrogen-free extract."

For sake of comparison, the minimum, maximum and average results of each experiment are given at the end of each table.

Tables 33, 37, 41, 45, 50, 54 and 58, contain the weights, in grams, of the samples at the time of harvest; weights and percentages of water-free corn in samples; and weights, in pounds, of corn and cobs, water-free corn and proximate ingredients from each plot of the different experiments. The weights of the samples are the results of the field weighings, checked by the laboratory weights. The "harvest weight" of corn multipled by the percentage of water-free corn in samples gives the weight of water-free corn per acre. The weights of the proximate ingredients were obtained by multiplying the weight of water-free corn on each plot by the analysis of water-free corn from that plot.

Tables 34, 38, 42, 46, 51, 55 and 59 contain the same weights for stover and its proximate ingredients as the tables just described for corn. The explanation for those tables will therefore suffice for these.

Tables 35, 39, 43, 47, 52, 56 and 60, contain the weights and cost per acre of the different fertilizers applied; the yield per acre, from the field weights and as calculated from the analyses; and the "gain or loss over nothing plots" of the different manured plots of each experiment. In 1888, the "harvest weights" of shelled corn were obtained by assuming that 90 pounds of "good" (sound ears) or 100 pounds of "poor" corn (soft ears and "nubbins") were equal to one bushel of shelled corn. In tables 35, 39, 43 and 47, the weights were thus calculated. In 1889 (tables 52, 56 and 60), the weights were estimated by analyzing a sample of corn made up of portions from all the plots of each experiment at harvesting, and calculating from the percentage of water-free corn thus found, the amount of corn, containing 11 per cent. of moisture, for each plot. As explained in the discussion of this subject on page 89 of the present Report, the weight of corn is calculated on this basis of moisture as that of average merchantable corn.

The weights of the total water-free substance, and of the principal nutritive ingredients of "corn plus stover," were obtained by adding together the weights of those constituents of corn and stover separately, as shown in the respective tables.

The gain or loss over "nothing" plots was found by subtracting the average number of bushels or pounds obtained on the unmanured plots of each experiment from the number of bushels or pounds on each manured plot.

TABLE 32.

Soil Test with Fertilizers on Corn, by A. C. Blake, 1888. Composition of Water-free Substance of Corn and Stover.

No. of Plot.	FERTILIZERS.	Laboratory No.	CORN.					Laboratory No.	STOVER.					
			Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.		Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Water in Stover at time of harvest.
			%	%	%	%	%		%	%	%	%	%	%
0, 00	Nothing,	603	11.13	5.13	80.48	1.55	1.71	604	4.69	1.64	50.66	37.25	5.76	41.34
A.	Nitrate of Soda,	605	10.94	5.12	80.85	1.50	1.59	606	5.63	2.12	50.27	36.66	5.32	36.54
B.	Dissolved Bone-black,	607	11.38	5.33	80.27	1.41	1.61	608	4.50	1.81	51.21	36.70	5.78	32.38
C.	Muriate of Potash,	609	9.88	5.25	81.66	1.55	1.66	610	4.31	2.05	50.97	36.77	5.90	50.03
D.	Nitrate of Soda, Dissolved Bone-black,	611	11.94	5.78	79.05	1.52	1.71	612	5.44	1.90	51.40	36.12	5.14	36.69
E.	Nitrate of Soda, Muriate of Potash,	613	12.94	5.43	78.43	1.52	1.68	614	5.50	1.79	49.63	37.05	6.03	41.99
F.	Dissolved Bone-black, Muriate of Potash,	615	10.75	5.35	80.62	1.63	1.65	616	4.38	1.75	51.16	36.55	6.16	46.84
G.	Nitrate of Soda, Muriate of Potash, Dissolved Bone-black,	617	11.69	5.26	79.70	1.59	1.76	618	4.81	1.55	51.21	36.31	6.12	40.92
	Minimum,	—	9.88	5.12	78.43	1.41	1.59	—	4.31	1.64	49.63	36.12	5.14	32.38
	Maximum,	—	12.94	5.78	81.66	1.63	1.76	—	5.63	2.12	51.21	37.25	6.16	50.03
	Average,	—	11.33	5.33	80.14	1.53	1.67	—	4.91	1.83	50.81	36.67	5.78	40.84

TABLE 33.

Soil Test with Fertilizers on Corn, by A. C. Blake, 1888. Proximate Ingredients in Corn per Acre.

No. of Plot.	FERTILIZERS.	Laboratory No.	IN SAMPLE.			CORN AND PROXIMATE INGREDIENTS PER ACRE.						
			Corn and Cobs at Harvest.	Water-free Corn.	Water-free Corn at Harvest.	Corn and Cobs at Harvest.	Water-free Corn.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			G.	G.	%	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0, 00	Nothing, - - - - - - - -	603	3629	1998	55.05	1895	1043	116.1	53.5	839.4	16.2	17.8
A.	Nitrate of Soda, - - - - - - -	605	2977	1644	55.21	2890	1596	174.6	81.7	1290.4	23.9	25.4
B.	Dissolved Bone-black, - - - -	607	2948	1618	54.89	2200	1208	137.5	64.4	969.7	17.0	19.4
C.	Muriate of Potash, - - - - -	609	2778	1438	51.76	2150	1113	110.0	58.4	908.9	17.2	18.5
D.	Nitrate of Soda, - - - - - - - Dissolved Bone-black, - - - -	611	3175	1758	55.38	2810	1556	185.8	89.9	1230.1	23.6	26.6
E.	Nitrate of Soda, - - - - - - - Muriate of Potash, - - - - -	613	3402	1848	54.31	3380	1836	237.6	99.7	1440.0	27.9	30.8
F.	Dissolved Bone-black, - - - - Muriate of Potash, - - - - -	615	3175	1675	52.76	2380	1256	135.0	67.2	1012.6	20.5	20.7
G.	Nitrate of Soda, - - - - - - - Dissolved Bone-black, - - - - Muriate of Potash, - - - - -	617	3402	1847	54.30	3500	1900	222.1	99.9	1514.4	30.2	33.4

Water-free Corn in above samples: Minimum, 51.76 per cent.; maximum, 55.21 per cent.; average, 54.21 per cent.

TABLE 34.

Soil Test with Fertilizers on Corn, by A. C. Blake, 1888. Proximate Ingredients in Stover per Acre.

No. of Plot.	FERTILIZERS.	Laboratory No.	IN SAMPLE.			STOVER AND PROXIMATE INGREDIENTS PER ACRE.						
			Stover at Harvest.	Water-free Stover.	Water-free Stover at Harvest.	Weight at Harvest.	Water-free Stover.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			G.	G.	%	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0, 00	Nothing, - - - - - - - -	604	1857	1089	58.66	1833	1075	50.6	17.6	544.4	400.4	62.0
A.	Nitrate of Soda, - - - - - - -	606	1304	827	63.46	2230	1415	79.6	30.1	711.3	518.6	75.4
B.	Dissolved Bone-black, - - - - - -	608	1602	1083	67.62	2120	1434	64.4	25.9	734.4	526.3	83.0
C.	Muriate of Potash, - - - - - - -	610	1800	899	49.97	2415	1207	51.9	24.6	615.2	444.0	71.3
D.	Nitrate of Soda, - - - - - - - Dissolved Bone-black, - - - - - -	612	1687	1068	63.31	2630	1665	90.7	31.6	855.7	601.5	85.5
E.	Nitrate of Soda, - - - - - - - Muriate of Potash, - - - - - -	614	2084	1209	58.01	2965	1720	94.6	30.8	853.6	637.2	103.8
F.	Dissolved Bone-black, - - - - - - Muriate of Potash, - - - - - - -	616	2027	1078	53.16	2745	1459	64.0	25.5	746.5	533.2	89.8
G.	Nitrate of Soda, - - - - - - - Dissolved Bone-black, - - - - - - Muriate of Potash, - - - - - - -	618	1793	1059	59.08	3211	1897	91.2	29.6	971.2	688.8	116.2

Water-free Stover in above samples: Minimum, 49.97 per cent.; maximum, 67.62 per cent.; average, 59.16 per cent.

TABLE 35.

Soil Test with Fertilizers on Corn, by A. C. Blake, 1888. Yield and Gain or Loss in Crop per Acre.

No. of Plot.	FERTILIZERS.			YIELD PER ACRE.							GAIN (OR LOSS –) PER ACRE OVER NOTHING PLOTS.							
	Kind.	Weight per Acre.	Cost per Acre.	Harvest W't.			W't from Analysis.				Corn.		Stover.		Corn and Stover.			
				Shld Corn			Corn and Stover.											
				Good.*	Poor.*	Stover.	Water-free Substance.	Protein.	Crude Fat.	Nitrogen-free Ex.	From Weight at Harvest.	From Analysis. (11 % water.)	From Weight at Harvest.	From Analysis. (water-free.)	Water-free Substance.	Protein.	Fat.	Nitrogen-free Extract.
		Lbs.	$	Bu.	Bu.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0, 00	Nothing, - - - -	—	—	19.0	1.8	1833	2118	167	71	1384	—	—	—	—	—	—	—	—
A.	Nitrate of Soda, - - -	150	4.95	30.2	1.7	2230	3011	254	112	2002	11.1	11.1	397	340	893	87	41	618
B.	Dissolved Bone-black, - -	350	5.65	23.6	.8	2120	2642	202	90	1704	3.6	3.3	287	359	524	35	19	320
C.	Muriate of Potash, - - -	150	4.34	22.2	1.5	2415	2322	162	83	1524	2.9	1.4	582	132	204	–5	12	140
D.	Nitrate of Soda, - - -	150	9.70	30.3	.8	2630	3221	277	122	2086	10.3	10.3	797	590	1103	110	51	702
	Dissolved Bone-black, - -	350																
E.	Nitrate of Soda, - - -	150	8.39	35.6	1.8	2965	3556	332	131	2294	16.6	15.8	1132	645	1438	165	60	910
	Muriate of Potash, - - -	150																
F.	Dissolved Bone-black, - -	350	9.09	25.6	.8	2745	2715	199	93	1759	5.6	4.3	912	384	597	32	22	375
	Muriate of Potash, - - -	150																
G.	Mixed Minerals, as F, - -	500	12.84	36.9	1.8	2810	3797	313	130	2486	17.9	17.1	977	822	1679	147	59	1102
	Nitrate of Soda, - - -	150																

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* Ninety pounds of "good" and 100 pounds of "poor" ears were assumed equal to one bushel of shelled corn.

TABLE 36.

Special Nitrogen Experiment of W. I. Bartholomew, 1888. Composition of Water-free Substance of Corn and Stover.

No. of Plot.	FERTILIZERS.	CORN.						STOVER.						
		Laboratory No.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Laboratory No.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Water in Stover at Harvest.
			%	%	%	%	%		%	%	%	%	%	%
0, 00,	Nothing,	629	13.06	5.65	78.34	1.42	1.53	630	10.06	2.57	48.33	31.09	7.95	65.29
1,	Nitrate of Soda,	627	13.25	5.34	78.31	1.50	1.60	628	9.75	2.37	49.20	31.75	6.93	65.55
2,	Dissolved Bone-black,	625	13.38	5.60	78.00	1.39	1.63	626	9.44	2.27	47.91	32.20	8.18	67.85
3,	Muriate of Potash,	623	13.06	5.23	78.34	1.66	1.71	624	10.19	2.19	49.53	31.20	6.89	62.34
4,	Nitrate of Soda, Dissolved Bone-black,	621	13.38	6.34	77.09	1.47	1.72	622	8.88	2.07	49.89	32.76	6.40	60.79
5,	Nitrate of Soda, Muriate of Potash,	619	13.13	5.64	78.19	1.54	1.50	620	9.31	2.16	47.68	33.15	7.70	66.24
6, a, b,	Dis. Bone-black, Mixed Mur. of Potash, Min's.	631	12.50	5.55	78.88	1.53	1.54	632	8.75	2.03	47.65	33.48	8.09	66.80
7, 10, 13,	Mixed Minerals, as No. 6, ⅓ Nitrogen ration,	633	12.44	5.70	78.84	1.44	1.58	634	8.06	2.18	49.12	33.10	7.54	71.36
8, 11, 14,	Mixed Minerals, as No. 6, ⅔ Nitrogen ration,	635	13.25	5.72	77.97	1.46	1.60	636	9.31	2.00	47.30	32.96	8.43	66.46
9, 12, 15,	Mixed Minerals, as No. 6, Full Nitrogen ration,	637	14.38	5.67	76.89	1.37	1.69	638	11.31	1.96	46.90	30.95	8.88	70.60
	Minimum,	—	12.44	5.23	76.89	1.37	1.50	—	8.06	1.96	46.90	30.95	6.40	60.79
	Maximum,	—	14.38	6.34	78.88	1.66	1.72	—	11.31	2.57	49.89	33.48	8.88	71.36
	Average,	—	13.18	5.64	78.09	1.48	1.61	—	9.51	2.18	48.35	32.26	7.70	66.33

TABLE 37.

Special Nitrogen Experiment of W. I. Bartholomew, 1888. Proximate Ingredients in Corn per Acre.

No. of Plot.	FERTILIZERS.	Laboratory No.	IN SAMPLE.			CORN AND PROXIMATE INGREDIENTS PER ACRE.						
			Corn and Cobs at Harvest.	Water-free Corn.	Water-free Corn at Harvest.	Corn and Cobs at Harvest.	Water-free Corn.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			G.	G.	%	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0, 00,	Nothing,	629	1736	793	45.69	2000	914	119.4	51.6	716.1	13.0	13.9
1,	Nitrate of Soda,	627	2140	983	45.91	2160	992	131.4	53.0	776.8	14.9	15.9
2,	Dissolved Bone-black,	625	2296	1079	46.98	3020	1419	189.9	79.5	1106.8	19.7	23.1
3,	Muriate of Potash,	623	1942	889	45.78	2710	1241	162.1	64.9	972.2	20.6	21.2
4,	Nitrate of Soda, Dissolved Bone-black,	621	1992	1039	52.16	3100	1617	216.4	102.5	1246.5	23.8	27.8
5,	Nitrate of Soda, Muriate of Potash,	619	2147	1044	48.63	2610	1269	166.6	71.6	992.3	19.5	19.0
6, a, b,	Mixed Minerals,	631	2381	1153	48.43	3890	1884	235.5	104.6	1486.1	28.8	29.0
7, 10, 13,	Mixed Minerals, as No. 6, One-third Nitrogen ration,	633	2381	1200	50.40	4047	2040	253.8	116.3	1608.3	29.4	32.2
8, 11, 14,	Mixed Minerals, as No. 6, Two-thirds Nitrogen ration,	635	2892	1428	49.37	4123	2036	269.8	116.5	1587.4	29.7	32.6
9, 12, 15,	Mixed Minerals, as No. 6, Full Nitrogen ration,	637	2410	1161	48.18	4047	1950	280.4	110.5	1499.5	26.7	32.9

Water-free Corn in above samples: Minimum, 45.69 per cent.; maximum, 52.16 per cent.; average, 48.15 per cent.

TABLE 38.

Special Nitrogen Experiment of W. I. Bartholomew, 1889. Proximate Ingredients in Stover per Acre.

No. of Plot.	FERTILIZERS.	Laboratory No.	IN SAMPLE.			STOVER AND PROXIMATE INGREDIENTS PER ACRE.						
			Stover at Harvest.	Water-free Stover.	Water-free Stover at Harvest.	Stover at Harvest.	Water-free Stover.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			G.	G.	%	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0, 00,	Nothing,	630	2254	782	34.71	2760	958	96.3	24.6	463.1	297.8	76.2
1,	Nitrate of Soda,	628	2417	833	34.45	2920	1006	98.1	23.9	494.7	319.5	69.8
2,	Dissolved Bone-black,	626	2722	875	32.15	3960	1273	120.4	28.9	609.8	409.8	104.1
3,	Muriate of Potash,	624	2112	795	37.66	2760	1039	105.8	22.8	514.6	324.2	71.6
4,	Nitrate of Soda, Dissolved Bone-black,	622	1871	734	39.21	3430	1345	119.4	27.8	671.0	440.7	86.1
5,	Nitrate of Soda, Muriate of Potash,	620	2877	971	33.76	3660	1236	114.9	26.7	589.5	409.7	95.2
6, a, b,	Mixed Minerals,	632	3083	1024	33.20	4583	1522	133.5	30.7	725.2	509.3	123.3
7, 10, 13,	Mixed Minerals, as No. 6, One-third Nitrogen ration,	634	3260	913	28.64	4683	1341	108.2	28.6	659.3	443.8	101.1
8, 11, 14,	Mixed Minerals, as No. 6, Two-thirds Nitrogen ration,	636	3374	1132	33.54	4857	1629	151.5	32.5	770.3	537.2	137.5
9, 12, 15,	Mixed Minerals, as No. 6, Full Nitrogen ration,	638	3501	1029	29.40	4970	1461	165.0	28.8	685.3	452.2	129.7

Water-free Stover in above samples: Minimum, 28.64 per cent.; maximum, 39.21 per cent.; average, 33.67 per cent.

TABLE 39.

Special Nitrogen Experiment of W. I. Bartholomew, 1888. Yield and Gain in Crop per Acre.

No. of Plot.	FERTILIZERS.			YIELD PER ACRE.							GAIN PER ACRE OVER NOTHING PLOTS.							
	Kind.	Weight per Acre.	Cost per Acre.	Harvest W't.			W't from Analysis.				Corn.		Stover.		Corn and Stover.			
				Shld Corn			Corn and Stover.											
				Good.*	Poor.*	Stover.	Water-free Substance.	Protein.	Crude Fat.	Nitrogen-free Ext.	From Weight at Harvest.	From Analysis. (11 % water.)	From Weight at Harvest.	From Analysis. (water-free.)	Water-free Substance.	Protein.	Fat.	Nitrogen-free Extract.
		Lbs.	$	Bu.	Bu.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Lbs.	Lbs	Lbs.	Lbs.	Lbs.
0, 00, -	Nothing, - - -	—	—	9.0	11.9	2760	1872	216	76	1179	—	—	—	—	—	—	—	—
1, - -	Nitrate of Soda, - -	150	4.95	10.3	12.3	2920	1998	230	77	1272	1.7	1.6	160	48	126	14	1	93
2, - -	Dissolved Bone-black, -	350	5.65	19.8	12.4	3960	2692	300	108	1717	11.3	10.1	1200	315	820	84	32	538
3, - -	Muriate of Potash, -	150	4.34	13.9	14.6	2760	2280	268	88	1487	7.6	6.5	000	81	408	52	12	308
4, - -	Nitrate of Soda, - - Dissolved Bone-black, -	150 350	9.70	22.9	10.4	3430	2962	336	130	1918	12.4	14.1	670	387	1090	120	54	739
5, - -	Nitrate of Soda, - - Muriate of Potash, -	150 150	8.39	13.7	13.8	3660	2505	282	98	1582	6.6	7.1	900	278	633	66	22	403
6, a, b, -	Dis. Bone-bl'k, } Mixed Mu. of Potash, } Min's.	350 150	9.09	32.4	9.7	4583	3400	369	135	2211	21.2	19.4	1823	564	1528	153	59	1032
7, 10, 13,	Mixed Minerals, as No. 6, ⅓ Nitrogen ration, -	500 —	13.03	35.6	8.5	4683	3381	362	145	2268	23.2	22.5	1923	383	1509	146	69	1089
8, 11, 14,	Mixed Minerals, as No. 6, ⅔ Nitrogen ration, -	500 —	16.97	35.5	9.3	4857	3665	421	149	2358	23.9	22.4	2097	671	1793	205	73	1179
9, 12, 15,	Mixed Minerals, as No. 6, Full Nitrogen ration, -	500 —	20.91	34.0	9.8	4970	3411	445	139	2185	22.9	20.7	2210	503	1539	229	63	1006

* Ninety pounds of "good" and 100 pounds of "poor" ears were assumed equal to one bushel of shelled corn.

TABLE 40.

Special Nitrogen Experiment of M. H. Dean, 1888. Composition of Water-free Substance of Corn and Stover.

No. of Plot.	FERTILIZERS.	CORN.						STOVER.						
		Laboratory No.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Laboratory No.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Water in Stover at Harvest.
			%	%	%	%	%		%	%	%	%	%	%
0, 00, -	Nothing, - - - - -	639	11.56	5.63	79.48	1.55	1.78	640	8.25	2.44	52.37	30.74	6.20	54.09
1, - -	Nitrate of Soda, - - - -	641	11.63	6.00	78.97	1.66	1.74	642	7.06	1.76	52.79	32.76	5.63	53.13
2, - -	Dissolved Bone-black, - -	643	11.06	5.58	79.96	1.55	1.85	644	6.94	2.21	52.43	31.83	6.59	59.26
3, - -	Muriate of Potash, - -	645	10.25	5.57	80.95	1.49	1.74	646	7.13	2.16	50.62	32.46	7.63	60.79
4, - -	Nitrate of Soda, - - - Dissolved Bone-black, - -	647	12.44	5.60	78.45	1.69	1.82	648	8.94	1.75	51.42	32.12	5.77	46.89
5, - -	Nitrate of Soda, - - - Muriate of Potash, - -	649	11.63	5.60	79.38	1.65	1.74	650	7.69	2.13	51.11	32.84	6.23	62.81
6, a, b, c, -	Mixed Minerals, - - -	651	9.88	5.64	81.16	1.56	1.76	652	6.13	2.61	51.55	32.48	7.23	56.55
7, 10, 13,	Mixed Minerals, as No. 6, - One-third Nitrogen ration, -	653	10.19	5.42	81.29	1.47	1.63	654	6.19	2.02	51.50	32.82	7.47	58.51
8, 11, 14,	Mixed Minerals, as No. 6, - Two-thirds Nitrogen ration, -	655	10.50	5.36	80.94	1.59	1.61	656	5.88	1.92	51.71	34.08	6.41	61.90
9, 12, 15,	Mixed Minerals, as No. 6, - Full Nitrogen ration, - -	657	11.75	5.63	79.40	1.52	1.70	658	7.31	1.88	48.58	35.60	6.63	63.91
	Minimum, - - - - -	—	9.88	5.36	78.45	1.47	1.61	—	5.88	1.75	48.58	30.74	5.63	46.89
	Maximum, - - - - -	—	12.44	6.00	81.29	1.69	1.85	—	8.94	2.61	52.79	35.60	7.63	63.91
	Average, - - - - -	—	11.09	5.60	80.00	1.57	1.74	—	7.15	2.09	51.41	32.77	6.58	57.78

TABLE 41.

Special Nitrogen Experiment of M. H. Dean, 1888. Proximate Ingredients in Corn per Acre.

No. of Plot.	FERTILIZERS.	Laboratory No.	IN SAMPLE.			CORN AND PROXIMATE INGREDIENTS PER ACRE.						
			Corn and Cobs at Harvest.	Water-free Corn.	Water-free Corn at Harvest.	Corn and Cobs at Harvest.	Water-free Corn.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			G.	G.	%	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0, 00, -	Nothing, - - - - -	639	1432	653	45.62	1450	662	76.5	37.3	526.1	10.3	11.8
1, - -	Nitrate of Soda, - - - - -	641	1999	974	48.72	2600	1267	147.4	76.0	1000.6	21.0	22.0
2, - -	Dissolved Bone-black, - - -	643	1956	932	47.65	2000	953	105.4	53.2	762.0	14.8	17.6
3, - -	Muriate of Potash, - - - -	645	2240	1027	45.85	3420	1568	160.7	87.3	1269.3	23.4	27.3
4, - -	Nitrate of Soda, - - - - - Dissolved Bone-black, - - -	647	1899	860	45.29	2400	1087	135.2	60.9	852.7	18.4	19.8
5, - -	Nitrate of Soda, - - - - - Muriate of Potash, - - - -	649	2303	1054	45.77	3880	1776	206.5	99.5	1409.8	29.3	30.9
6, a, b, -	Mixed Minerals, - - - - -	651	2367	1173	49.56	3020	1497	147.9	84.4	1215.0	23.4	26.3
7, 10, 13,	Mixed Minerals, as No. 6, - - ⅓ Nitrogen ration, - - - -	653	2339	1185	50.66	4027	2040	207.9	110.6	1658.4	29.9	33.2
8, 11, 14,	Mixed Minerals, as No. 6, - - ⅔ Nitrogen ration, - - - -	655	2622	1318	50.27	4487	2256	236.9	120.9	1826.0	35.9	36.3
9, 12, 15,	Mixed Minerals, as No. 6, - - Full Nitrogen ration, - - -	657	3338	1714	51.35	4713	2420	284.4	136.2	1921.4	36.8	41.2

Water-free Corn in above samples: Minimum, 45.29 per cent.; maximum, 51.35 per cent.; average, 48.07 per cent.

TABLE 42.

Special Nitrogen Experiment of M. H. Dean, 1888. Proximate Ingredients in Stover per Acre.

No. of Plot.	FERTILIZERS.	Laboratory No.	IN SAMPLE.			STOVER AND PROXIMATE INGREDIENTS PER ACRE.						
			Stover at Harvest.	Water-free Stover.	Water-free Stover at Harvest.	Stover at Harvest.	Water-free Stover.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			G.	G.	%	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0, 00, -	Nothing, - - - - - - -	640	1956	898	45.91	2750	1263	104.3	30.8	661.3	388.2	78.4
1, - -	Nitrate of Soda, - - - - - -	642	2183	1023	46.87	3880	1819	128.4	32.3	960.1	595.8	102.4
2, - -	Dissolved Bone-black, - - - - -	644	1914	780	40.74	3640	1483	103.0	32.8	777.6	472.1	97.5
3, - -	Muriate of Potash, - - - - -	646	2176	854	39.21	4460	1749	124.9	37.9	884.9	567.9	133.4
4, - -	Nitrate of Soda, - - - - - Dissolved Bone-black, - - - -	648	1729	918	53.11	3700	1965	175.8	34.4	1010.4	631.2	113.2
5, - -	Nitrate of Soda, - - - - - Muriate of Potash, - - - -	650	2849	1059	37.19	4640	1726	132.7	36.7	882.3	566.7	107.6
6, a, b, c,	Mixed Minerals, - - - - - -	652	2381	1035	43.45	4360	1894	116.0	49.7	976.4	615.0	136.9
7, 10, 13,	Mixed Minerals, as No. 6, - - - One-third Nitrogen ration, - - -	654	2637	1094	41.49	5187	2152	133.3	43.6	1107.8	706.5	160.8
8, 11, 14,	Mixed Minerals, as No. 6, - - - Two-thirds Nitrogen ration, - - -	656	2778	1058	38.10	6080	2317	136.2	44.4	1197.9	790.5	148.5
9, 12, 15,	Mixed Minerals, as No. 6, - - - Full Nitrogen ration, - - -	658	3459	1248	36.09	6493	2343	171.4	44.2	1138.0	834.2	155.2

Water-free Stover in above samples: Minimum, 36.09 per cent.; maximum, 46.87 per cent.; average, 42.22 per cent.

TABLE 43.

Special Nitrogen Experiment of M. H. Dean, 1888. Yield and Gain in Crop per Acre.

No. of Plot.	FERTILIZERS.			YIELD PER ACRE.							GAIN PER ACRE OVER NOTHING PLOTS.							
				Harvest Weights.			W'ts from Analysis.				Corn.		Stover.		Corn and Stover.			
				Sh'l'd Corn.			Corn and Stover.											
	Kind.	Weight per Acre.	Cost per Acre.	Good.*	Poor.*	Stover.	Water-free Substance.	Protein.	Crude Fat.	Nitrogen-free Ex.	From Weight at Harvest.	From Analysis. (11 % water.)	From Weight at Harvest.	From Analysis. (Water-free.)	Water-free Substance.	Protein.	Fat.	Nitrogen-free Extract.
		Lbs.	$	Bu.	Bu.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0, 00, -	Nothing, - - - -	—	—	13.0	2.8	2750	1925	181	68	1187	—	—	—	—	—	—	—	—
1, - -	Nitrate of Soda, - -	150	4.95	25.8	2.8	3880	3086	276	108	1961	12.8	12.1	1130	556	1161	95	40	774
2, - -	Dissolved Bone-black,	350	5.65	19.6	2.4	3640	2436	209	86	1540	6.2	5.8	890	220	511	28	18	353
3, - -	Muriate of Potash, -	150	4.34	35.3	2.4	4460	3317	286	125	2154	21.9	18.1	1710	486	1392	105	57	967
4, - -	Nitrate of Soda, - Dissolved Bone-black,	150 350	9.70	21.8	4.4	3700	3052	311	95	1863	10.4	8.5	950	702	1127	130	27	676
5, - -	Nitrate of Soda, - - Muriate of Potash, -	150 150	8.39	39.1	3.6	4640	3502	339	136	2292	26.9	22.3	1890	463	1577	158	68	1105
6, a, b, -	Dis. Bone-bl'k } Mixed Mu. of Potash, } Min'ls	350 150	9.09	30.8	2.5	4360	3391	264	134	2191	17.5	16.7	1610	631	1466	83	66	1004
7, 10, 13,	Mix'd Minr'ls, as No. 6, ⅓ Nitrogen ration, -	500 —	13.03	42.0	2.5	5187	4192	341	154	2766	28.7	27.6	2437	889	2267	160	86	1579
8, 11, 14,	Mix'd Minr'ls, as No. 6, ⅔ Nitrogen ration, -	500 —	16.97	46.5	3.1	6080	4572	373	165	3024	33.8	31.9	3330	1054	2647	192	97	1837
9, 12, 15,	Mix'd Minr'ls, as No. 6, Full Nitrogen ration, -	500 —	20.91	48.1	3.9	6493	4763	456	180	3059	36.2	38.6	3743	1080	2838	275	112	1872

* Ninety pounds of "good" and 100 pounds of "poor" ears were assumed equal to one bushel of shelled corn.

TABLE 44.

Special Nitrogen Experiment of the Station, 1888. Composition of Water-free Substance of Corn and Stover.

No. of Plot.	FERTILIZERS.	CORN.						STOVER.						
		Laboratory No.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Crude Ash.	Laboratory No.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Water in Stover at Harvest.
			%	%	%	%	%		%	%	%	%	%	%
0, 00, -	Nothing, - - - -	659	12.06	5.32	79.38	1.63	1.61	660	7.13	1.59	48.25	35.87	7.16	43.01
6, a, b, c,	Mixed Minerals, - -	661	11.44	5.57	79.72	1.62	1.65	662	7.06	1.61	48.56	35.22	7.55	52.68
7, 10, 13,	Mixed Minerals, as No. 6, ⅓ Nitrogen ration, - -	663	12.69	5.45	78.44	1.81	1.61	664	8.19	1.84	46.73	35.66	7.58	55.52
8, 11, 14,	Mixed Minerals, as No. 6, ⅔ Nitrogen ration, - -	665	12.19	5.66	78.90	1.67	1.58	666	7.94	1.91	48.33	34.87	6.95	52.76
9, 12, 15,	Mixed Minerals, as No. 6, Full Nitrogen ration, -	667	13.19	5.59	77.93	1.69	1.60	668	8.69	1.42	45.87	34.49	9.53	51.92
	Minimum, - - -	—	11.44	5.32	77.93	1.62	1.58	—	7.06	1.42	45.87	34.49	6.95	43.01
	Maximum, - - -	—	13.19	5.66	79.72	1.81	1.65	—	8.69	1.91	48.56	35.87	9.53	55.52
	Average, - - - -	—	12.31	5.52	78.88	1.68	1.61	—	7.80	1.67	47.55	35.22	7.76	51.18

TABLE 45.

Special Nitrogen Experiment of the Station, 1888. Proximate Ingredients in Corn per Acre.

No. of Plot.	FERTILIZERS.	Laboratory No.	IN SAMPLE.			CORN AND PROXIMATE INGREDIENTS PER ACRE.						
			Corn and Cobs at Harvest.	Water-free Corn.	Water-free Corn at Harvest.	Corn and Cobs at Harvest.	Water-free Corn.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			G.	G.	%	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0, 00, -	Nothing, - - - - - -	659	1510	835	55.30	1890	1045	126.1	55.6	829.5	17.0	16.8
6, a, b, c,	Mixed Minerals, - - - -	661	1814	934	51.49	2540	1308	149.4	72.9	1042.9	21.2	21.6
7, 10, 13,	Mixed Minerals, as No. 6, - - One-third Nitrogen ration, - -	663	1446	725	50.14	2827	1417	179.8	77.2	1111.5	25.7	22.8
8, 11, 14,	Mixed Minerals, as No. 6, - - Two-thirds Nitrogen ration, - -	665	1843	1021	55.40	2927	1622	199.1	90.2	1279.9	27.1	25.7
9, 12, 15,	Mixed Minerals, as No. 6, - - Full Nitrogen ration, - - -	667	1765	936	53.03	2720	1442	190.2	80.6	1123.7	24.4	23.1

Water-free Corn in above samples: Minimum, 50.14 per cent.; maximum, 55.40 per cent.; average, 53.07 per cent.

TABLE 46.

Special Nitrogen Experiment of the Station, 1888. Proximate Ingredients in Stover per Acre.

No. of Plot.	FERTILIZERS.	Laboratory No.	IN SAMPLE.			STOVER AND PROXIMATE INGREDIENTS PER ACRE.						
			Stover at Harvest.	Water-free Stover.	Water-free Stover at Harvest.	Stover at Harvest.	Water-free Stover.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			G.	G.	%	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0, 00, -	Nothing, - - - - - - -	660	1658	945	56.99	2730	1556	110.8	24.8	750.9	558.1	111.4
6, a, b, c,	Mixed Minerals, - - - -	662	2041	966	47.32	3205	1517	107.0	24.4	736.7	534.5	114.4
7, 10, 13,	Mixed Minerals, as No. 6, - - One-third Nitrogen ration, - -	664	1921	854	44.48	3640	1619	132.5	29.8	756.7	577.3	122.7
8, 11, 14,	Mixed Minerals, as No. 6, - - Two-thirds Nitrogen ration, - -	666	1914	904	47.24	3760	1776	141.0	33.8	858.7	619.4	123.3
9, 12, 15,	Mixed Minerals, as No. 6, - - Full Nitrogen ration, - - -	668	1793	862	48.08	3580	1721	149.6	24.3	789.6	593.5	164.1

Water-free Stover in above samples: Minimum, 44.48 per cent.; maximum, 56.99 per cent.; average, 48.82 per cent.

TABLE 47.

Special Nitrogen Experiment of the Station, 1888. Yield and Gain or Loss in Crop per Acre.

No. of Plot.	FERTILIZERS.			YIELD PER ACRE.							GAIN OR LOSS OVER NOTHING PLOTS.							
				Harvest Weights.			Wts. from Analysis.											
	Kind.	Weight per Acre.	Cost per Acre,	Sh'll'd Corn.		Stover.	Corn and Stover.				Corn.		Stover.		Corn and Stover.			
				Good.*	Poor.*		Water-free Substance.	Protein.	Crude Fat.	Nitrogen-free Extract.	From Weight at Harvest.	From Analysis. (11 % Water.)	From Weight at Harvest.	From Analysis (Water-free.)	Water-free Substance.	Protein.	Fat.	Ash.
		Lbs.	$	Bu.	Bu.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0,00 -	Nothing, - - -	—	—	7.2	12.4	2730	2601	237	80	1580	—	—	—	—	—	—	—	—
6, a, b, c,	Dis. Bone-bl'k, Mixed Mu. of Potash, Min's.	350 150	9.09	13.5	12.2	3205	2825	257	97	1780	6.1	5.3	475	−39	224	20	17	200
7, 10, 13,	Mixed Min'ls, as No. 6, ⅓ Nitrogen ration, -	500 —	13.03	18.7	11.6	3640	3036	312	107	1868	10.7	7.4	910	63	435	75	27	288
8, 11, 14,	Mixed Min'ls, as No. 6, ⅔ Nitrogen ration, -	500 —	16.97	20.4	10.9	3760	3398	340	124	2139	11.7	11.5	1030	220	797	103	44	559
9, 12, 15,	Mixed Min'ls, as No. 6, Full Nitrogen ration, -	500 —	20.91	17.9	11.1	3580	3163	340	105	1913	9.4	7.9	850	165	562	103	25	333

* Ninety pounds of "good" and 100 pounds of "poor" ears were assumed equal to 1 bushel of shelled corn.

TABLE 48.

Special Nitrogen Experiment of L. J. Wells, 1888. Composition of Water-free Substance of Corn and Stover.

No. of Plot.	FERTILIZERS.	CORN.						STOVER.						
		Laboratory No.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Laboratory No.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Water at Harvest.
			%	%	%	%	%		%	%	%	%	%	%
0, 00, - -	Nothing, - - -	669	11.56	5.25	79.86	1.74	1.59	670	8.94	1.89	50.67	31.37	7.13	62.08
1, - -	Nitrate of Soda, - -	671	12.25	5.24	79.11	1.74	1.66	672	8.81	1.97	49.85	33.90	5.47	53.29
2, - -	Dissolved Bone-black, -	673	11.63	5.35	79.67	1.72	1.63	674	8.94	2.27	49.96	32.35	6.48	51.96
3, - -	Muriate of Potash, -	675	10.88	5.08	80.86	1.63	1.55	676	7.81	2.06	49.96	32.32	7.85	56.15
4, - -	Nitrate of Soda, - - Dissolved Bone-black, -	677	12.00	5.36	79.23	1.57	1.84	678	8.31	1.92	49.90	33.27	6.60	57.68
5, - -	Nitrate of Soda, - - Muriate of Potash, - -	679	10.50	5.54	81.01	1.35	1.60	680	8.75	2.10	49.88	31.86	7.41	59.11
6, a, b, c,	Mixed Minerals, - -	681	10.94	5.21	80.61	1.62	1.62	682	6.06	2.09	51.36	33.92	6.57	60.37
7, 10, 13,	Mixed Minerals, as No. 6, ⅓ Nitrogen ration, -	683	12.69	6.15	77.90	1.49	1.77	684	7.38	2.11	52.41	32.53	5.57	64.40
8, 11, 14,	Mixed Minerals, as No. 6, ⅔ Nitrogen ration, -	685	11.75	5.65	79.39	1.50	1.71	686	7.44	1.97	51.87	33.09	5.63	61.95
9, 12, 15,	Mixed Minerals, as No. 6, Full Nitrogen ration, -	687	12.00	5.10	79.74	1.53	1.63	688	7.53	1.88	51.55	32.83	6.21	63.85
	Minimum, - - -	—	10.50	5.08	79.11	1.35	1.55	—	6.06	1.88	49.85	31.37	5.47	51.96
	Maximum, - - -	—	12.69	6.15	81.01	1.74	1.84	—	8.94	2.11	52.41	33.90	7.85	64.40
	Average, - - -	—	11.62	5.39	79.74	1.59	1.66	—	8.00	2.03	50.74	32.74	6.49	59.98

TABLE 49.

Special Nitrogen Experiment of M. H. Dean, 1889. Composition of Water-free Substance of Corn and Stover.

No. of Plot.	FERTILIZERS.	CORN.							STOVER.						
		Laboratory No.	Protein.	Crude Fat.	Nitg'n-free Extract.	Fiber.	Ash.	Water at time of Harvest.	Laboratory No.	Protein.	Crude Fat.	Nitg'n-free Extract.	Fiber.	Ash.	Water at time of Harvest.
			%	%	%	%	%	%		%	%	%	%	%	%
0, 00	Nothing,	695	12.50	5.30	78.44	1.88	1.88	27.42	694	7.94	1.77	48.49	36.34	5.46	44.84
1.	Nitrate of Soda,	697	12.75	5.11	77.95	2.27	1.92	30.80	696	9.63	1.69	54.59	29.69	4.40	49.76
2.	Dissolved Bone-black,	699	13.25	5.30	77.38	2.06	2.01	29.22	698	9.38	1.68	52.97	30.73	5.24	47.44
3.	Muriate of Potash,	701	10.19	5.65	80.43	1.84	1.89	28.35	700	5.63	1.94	56.99	29.97	5.47	48.89
4.	Nitrate of Soda, Dissolved Bone-black,	703	12.44	6.87	77.12	1.58	1.99	28.93	702	9.31	1.71	53.57	30.25	5.16	52.23
5.	Nitrate of Soda, Muriate of Potash,	705	10.44	6.26	79.33	1.86	2.11	27.96	704	5.50	1.73	52.51	34.28	5.98	49.77
6, a, b, c,	Dissolved Bone-black, Muriate of Potash, } Mixed Minerals,	725	9.69	6.27	80.52	1.69	1.83	27.19	724	4.63	2.19	56.66	31.13	5.39	54.57
7.	Mixed Minerals, as No. 6, Nitrate of Soda, ⅓ ration,	707	10.50	7.22	78.23	1.99	2.06	26.85	706	4.75	1.72	53.63	34.22	5.68	52.96
8.	Mixed Minerals, as No. 6, Nitrate of Soda, ⅔ ration,	709	11.25	7.12	77.60	1.96	2.07	27.43	708	5.19	1.70	52.45	35.24	5.42	46.74
9.	Mixed Minerals, as No. 6, Nitrate of Soda, full ration,	711	9.88	7.03	79.14	1.83	2.12	27.96	710	5.63	1.83	53.21	34.11	5.22	54.41
10.	Mixed Minerals, as No. 6, Sulphate of Ammonia, ⅓ ration,	713	9.00	6.48	80.94	1.74	1.84	26.99	712	5.06	1.85	55.58	32.14	5.37	55.18
11.	Mixed Minerals, as No. 6, Sulphate of Ammonia, ⅔ ration,	715	8.94	6.78	80.85	1.64	1.79	28.13	714	4.06	1.75	53.60	34.79	5.80	55.61
12.	Mixed Minerals, as No. 6, Sulphate of Ammonia, full ration,	717	11.13	6.18	78.96	1.85	1.88	27.78	716	4.94	1.32	51.62	36.50	5.62	50.37
13.	Mixed Minerals, as No. 6, Dried Blood, ⅓ ration,	719	9.81	6.94	79.39	1.88	1.98	28.30	718	4.56	1.76	54.74	33.31	5.63	57.44
14.	Mixed Minerals, as No. 6, Dried Blood, ⅔ ration,	721	9.06	5.93	81.37	1.84	1.80	27.66	720	4.50	1.92	53.32	34.74	5.52	55.78
15.	Mixed Minerals, as No. 6, Dried Blood, full ration,	723	9.19	6.09	80.98	1.89	1.85	28.04	722	4.38	1.70	53.82	34.45	5.65	54.20
	Minimum,	—	8.94	5.11	77.12	1.58	1.80	26.85	—	4.06	1.32	48.49	29.69	4.40	44.84
	Maximum,	—	13.25	7.22	81.37	2.27	2.12	30.80	—	9.63	2.19	56.99	36.50	5.80	57.44
	Average,	—	10.63	6.28	79.29	1.86	1.94	28.06	—	5.94	1.77	53.61	33.24	5.44	51.89

TABLE 50.

Special Nitrogen Experiment of M. H. Dean, 1889. Proximate Ingredients in Corn per Acre.

No. of Plot.	FERTILIZERS.	Laboratory No.	IN SAMPLE.			CORN AND PROXIMATE INGREDIENTS PER ACRE.						
			Corn and Cobs at Harvest.	Water-free Corn.	Water-free Corn at Harvest.	Corn and Cobs at Harvest.	Water-free Corn.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			G.	G.	%	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0, 00, -	Nothing, - - - - - - -	695	1276	691	54.15	430	233	29.1	12.4	182.8	4.4	4.4
1, - -	Nitrate of Soda, - - - - - -	697	1198	591	49.33	660	325	41.4	16.6	253.3	7.4	6.3
2, - -	Dissolved Bone-black, - - - - -	699	910	453	49.78	460	229	30.4	12.2	177.1	4.7	4.6
3, - -	Muriate of Potash, - - - - -	701	2018	1087	53.87	2140	1153	117.5	65.1	927.4	21.2	21.8
4, - -	Nitrate of Soda, - - - - - Dissolved Bone-black, - - - -	703	1512	786	51.87	900	467	58.1	32.1	360.1	7.4	9.3
5, - -	Nitrate of Soda, - - - - - Muriate of Potash, - - - -	705	2060	1118	54.27	2600	1411	147.3	88.4	1119.3	26.2	29.8
6, a, b, c,	Dissolved Bone-black, } Mixed Minerals, Muriate of Potash, }	725	3027	1698	56.10	1440	808	78.3	50.7	650.6	13.6	14.8
7, - -	Mixed Minerals, as No. 6, - - - Nitrate of Soda, one-third ration, - -	707	2148	1215	56.57	3560	2014	211.5	145.4	1575.5	40.1	41.5
8, - -	Mixed Minerals, as No. 6, - - - Nitrate of Soda, two-thirds ration, -	709	2786	1587	56.96	4680	2666	300.0	189.8	2068.7	52.3	55.2
9, - -	Mixed Minerals, as No. 6, - - - Nitrate of Soda, full ration, - - -	711	2181	1234	56.58	4400	2490	246.0	175.0	1970.6	45.6	52.8
10, - -	Mixed Minerals, as No. 6, - - - Sulphate of Ammonia, one-third ration.	713	2189	1225	55.96	2420	1354	121.8	87.8	1096.0	23.5	24.9
11, - -	Mixed Minerals, as No. 6, - - - Sulphate of Ammonia, two-thirds ration,	715	2307	1280	55.48	4360	2419	216.2	164.0	1955.8	39.7	43.3
12, - -	Mixed Minerals, as No. 6, - - - Sulphate of Ammonia, full ration, -	717	2302	1292	56.12	4800	2694	299.9	166.5	2127.1	49.8	50.7
13, - -	Mixed Minerals, as No. 6, - - - Dried Blood, one-third ration, - -	719	2124	1183	55.70	2320	1292	126.7	89.7	1025.7	24.3	25.6
14, - -	Mixed Minerals, as No. 6, - - - Dried Blood, two-thirds ration, - -	721	2240	1258	56.16	3260	1831	165.6	108.6	1490.2	33.7	32.9
15, - -	Mixed Minerals, as No. 6, - - - Dried Blood, full ration, - - -	723	2172	1201	55.30	3800	2102	193.1	128.0	1702.2	39.8	38.9

Water-free Corn in above: Minimum, 49.33 per cent.; maximum, 56.96 per cent.; average, 54.64 per cent.

TABLE 51.

Special Nitrogen Experiment of M. H. Dean, 1889. Proximate Ingredients in Stover per Acre.

No. of Plot.	FERTILIZERS.	Laboratory No.	IN SAMPLE.			STOVER AND PROXIMATE INGREDIENTS PER ACRE.						
			Stover at Harvest.	Water-free Stover.	Water-free Stover at Harvest.	Stover at Harvest.	Water-free Stover.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			G.	G.	%	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0, 00, -	Nothing, - - - - - - -	694	2152	1187	55.16	1030	568	45.1	9.8	275.5	206.5	31.1
1, - -	Nitrate of Soda, - - - - - -	696	1871	940	50.24	1300	653	62.9	11.0	356.5	193.9	28.7
2, - -	Dissolved Bone-black, - - - - -	698	1233	648	52.56	1080	568	53.3	9.5	300.9	174.5	29.8
3, - -	Muriate of Potash, - - - - -	700	2070	1058	51.11	2600	1329	74.9	25.8	757.3	398.3	72.7
4, - -	Nitrate of Soda, - - - - - - Dissolved Bone-black, - - - - -	702	1729	826	47.77	1620	774	72.1	13.2	414.6	234.1	40.0
5, - -	Nitrate of Soda, - - - - - - Muriate of Potash, - - - - -	704	1758	883	50.23	3500	1758	96.7	30.5	923.1	602.6	105.1
6, a, b, c,	Dissolved Bone-black, } Mixed Minerals, Muriate of Potash, }	724	2877	1307	45.43	2970	1349	62.5	29.6	764.3	419.9	72.7
7, - -	Mixed Minerals, as No. 6, - - - Nitrate of Soda, one-third ration, - -	706	2013	974	47.04	3640	1712	81.3	29.5	918.2	585.8	97.2
8, - -	Mixed Minerals, as No. 6, - - - Nitrate of Soda, two-thirds ration, -	708	2270	1209	53.26	4080	2173	112.8	36.9	1139.7	765.7	117.9
9, - -	Mixed Minerals, as No. 6, - - - Nitrate of Soda, full ration, - - -	710	2551	1163	45.59	4000	1824	102.7	33.4	970.5	622.2	95.2
10, - -	Mixed Minerals, as No. 6, - - - Sulphate of Ammonia, one-third ration,	712	2367	1061	44.82	3840	1721	87.0	31.8	956.6	553.1	92.5
11, - -	Mixed Minerals, as No. 6, - - - Sulphate of Ammonia, two-thirds ration,	714	1899	843	44.39	4380	1944	79.0	34.0	1042.0	676.3	112.7
12, - -	Mixed Minerals, as No. 6, - - - Sulphate of Ammonia, full ration, - -	716	1914	950	49.63	4160	2065	102.0	27.2	1066.0	753.7	116.1
13, - -	Mixed Minerals, as No. 6, - - - Dried Blood, one-third ration, - -	718	2211	941	42.56	3340	1422	64.8	25.0	778.4	473.6	80.2
14, - -	Mixed Minerals, as No. 6, - - - Dried Blood, two-thirds ration, - -	720	1999	884	44.22	4360	1928	86.8	37.0	1028.1	669.8	106.3
15, - -	Mixed Minerals, as No. 6, - - - Dried Blood, full ration, - - -	722	1417	649	45.80	4780	2189	95.9	37.2	1178.1	754.1	123.7

Water-free Stover in above samples: Minimum, 42.56 per cent.; maximum, 55.16 per cent.; average, 48.11 per cent.

TABLE 52.

Special Nitrogen Experiment of M. H. Dean, 1889. Yield and Gain or Loss in Crop per Acre.

No. of Plot.	FERTILIZERS.			YIELD PER ACRE.							GAIN (OR LOSS -) PER ACRE OVER NOTHING PLOTS.							
	Kind.	Weight per Acre.	Cost per Acre.	Harvest Weights.			Weights from Analysis.				Corn. (11 % water.)		Stover.		Corn and Stover.			
				Shelled Corn. (11 % water.)		Stover.	Corn and Stover.				From Weight at Harvest.	From Analysis.	From Weight at Harvest.	From Anal. (water-free.)	Water-free Substance.	Protein.	Fat.	Nit.-free Ext.
				Good.	Poor.		Water-free Sub.	Protein.	Crude Fat.	Nit.-free Ext.								
		Lbs.	$	Bu.	Bu.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0, -	Nothing, - - - - -	—	—	2.1	2.7	1030	801	74	22	458	—	—	—	—	—	—	—	—
1, -	Nitrate of Soda, - -	160	4.20	4.3	3.2	1300	978	104	28	610	2.7	1.8	270	85	177	30	6	152
2, -	Dissolved Bone-black, -	320	4.16	3.1	2.1	1080	797	84	22	478	0.4	-0.1	50	0	-4	10	0	20
3, -	Muriate of Potash, - -	160	3.36	22.8	2.5	2600	2482	192	91	1685	20.5	18.4	1570	761	1681	118	69	1227
4, -	Nitrate of Soda, - -	160	8.84	7.2	3.2	1620	1241	130	45	775	5.6	4.7	590	206	440	56	23	317
	Dissolved Bone-black, -	320																
5, -	Nitrate of Soda, - -	160	7.88	27.6	3.2	3500	3169	244	119	2042	26.0	23.6	2470	1190	2368	170	97	1584
	Muriate of Potash, - -	160																
6,a, b,c,	Dis. Bone-black, Mixed	320	8.00	13.7	3.1	2970	2157	141	80	1415	12.0	11.5	1940	781	1356	67	58	957
	Muriate of Potash, Mnr'l,	160																
7, -	Mixed Minerals, as No. 6,	480	12.36	40.8	1.7	3640	3726	293	175	2494	37.7	35.6	2610	1144	2925	219	153	2036
	Nitrate of Soda, ⅓ ration,	160																
8, -	Mixed Minerals, as No. 6,	480	16.72	52.8	3.0	4080	4839	413	227	3208	51.0	48.7	3050	1605	4038	339	205	2750
	Nitrate of Soda, ⅔ ration,	320																
9, -	Mixed Minerals, as No. 6,	480	21.08	48.0	4.2	4000	4314	349	208	2941	47.4	45.1	2970	1256	3513	275	186	2483
	Nitrate of Soda, full ration,	480																
10, -	Mixed Minerals, as No. 6,	480	12.60	24.2	4.2	3840	3075	209	120	2053	23.6	22.4	2810	1153	2274	135	98	1595
	Sul. of Ammonia, ⅓ ration,	120																
11, -	Mixed Minerals, as No. 6,	480	17.24	48.0	3.8	4380	4363	295	198	2998	47.0	43.7	3350	1376	3562	221	176	2540
	Sul. of Ammonia, ⅔ ration,	240																
12, -	Mixed Minerals, as No. 6,	480	21.86	53.2	3.8	4160	4759	402	194	3193	52.2	49.2	3130	1497	3958	328	172	2735
	Sul. of Ammonia, full ration,	360																
13, -	Mixed Minerals, as No. 6,	480	12.16	25.7	1.9	3340	2714	192	115	1804	22.8	21.2	2310	854	1913	118	93	1346
	Dried Blood, ⅓ ration, -	160																
14, -	Mixed Minerals, as No. 6,	480	16.32	36.2	2.5	4360	3759	252	146	2518	33.9	32.0	3330	1360	2958	178	124	2060
	Dried Blood, ⅔ ration, -	320																
15, -	Mixed Minerals, as No. 6,	480	20.48	43.6	1.7	4780	4291	289	165	2880	40.5	37.4	3750	1621	3490	214	143	2422
	Dried Blood, full ration, -	480																

TABLE 53.

Special Nitrogen Experiment of E. H. Lathrop, 1889. Composition of Water-free Substance of Corn and Stover.

No. of Plot.	FERTILIZERS.	CORN.							STOVER.						
		Laboratory No.	Protein.	Crude Fat.	Nitg'n-free Extract.	Fiber.	Ash.	Water at time of Harvest.	Laboratory No.	Protein.	Crude Fat.	Nitg'n-free Extract.	Fiber.	Ash.	Water at time of Harvest.
			%	%	%	%	%	%		%	%	%	%	%	%
0, 00	Nothing,	727	11.44	6.01	78.25	2.25	2.05	29.72	726	6.44	2.07	51.85	33.91	5.73	44.01
2.	Dissolved Bone-black,	729	10.44	5.18	80.49	2.05	1.84	27.62	728	4.69	2.03	53.10	34.81	5.37	38.20
3.	Muriate of Potash,	731	10.38	4.93	80.90	2.06	1.73	29.75	730	4.44	1.82	55.71	32.58	5.45	48.03
6, a,	Dissolved Bone-black, Muriate of Potash, Mixed Minerals,	733	10.88	6.78	77.95	2.22	2.17	30.06	732	5.06	1.73	54.95	31.83	6.43	52.83
7.	Mixed Minerals, as No. 6, Nitrate of Soda, ⅓ ration,	735	10.50	5.78	79.90	2.05	1.77	27.26	734	4.94	1.77	54.04	33.90	5.35	39.50
8.	Mixed Minerals, as No. 6, Nitrate of Soda, ⅔ ration,	737	11.00	5.77	79.35	2.11	1.77	28.89	736	5.25	1.85	52.94	34.17	5.79	40.09
9.	Mixed Minerals, as No. 6, Nitrate of Soda, full ration,	739	11.19	6.14	78.15	2.24	2.28	28.85	738	5.56	2.09	51.76	34.98	5.61	45.02
10.	Mixed Minerals, as No. 6, Sulphate of Ammonia, ⅓ ration,	741	10.31	5.80	79.56	2.41	1.92	29.72	740	5.36	1.79	52.34	34.24	6.27	47.27
11.	Mixed Minerals, as No. 6, Sulphate of Ammonia, ⅔ ration,	743	12.06	5.92	77.82	2.27	1.93	28.41	742	5.13	1.38	51.03	36.85	5.61	47.91
12.	Mixed Minerals, as No. 6, Sulphate of Ammonia, full ration,	745	11.50	6.38	78.05	2.07	2.00	26.92	744	6.44	2.02	51.05	34.75	5.74	49.75
13.	Mixed Minerals, as No. 6, Dried Blood, ⅓ ration,	747	10.06	5.71	80.38	2.00	1.85	27.50	746	4.69	1.84	52.89	34.09	6.49	45.08
14.	Mixed Minerals, as No. 6, Dried Blood, ⅔ ration,	749	9.63	4.99	81.94	1.86	1.58	27.70	748	3.69	1.97	53.49	34.89	5.96	46.69
15.	Mixed Minerals, as No. 6, Dried Blood, full ration,	751	10.31	5.65	80.15	2.08	1.81	28.98	750	4.56	2.10	52.05	35.41	5.88	40.99
	Minimum,	—	9.63	4.93	77.82	1.86	1.58	26.92	—	4.44	1.73	51.03	31.83	5.35	38.20
	Maximum,	—	12.06	6.78	81.94	2.41	2.28	30.06	—	6.44	2.10	55.71	36.85	6.49	52.83
	Average,	—	10.75	5.77	79.45	2.13	1.90	28.57	—	5.10	1.88	52.86	34.34	5.82	45.03

TABLE 54.

Special Nitrogen Experiment of E. H. Lathrop, 1889. Proximate Ingredients in Corn per Acre.

No. of Plot.	FERTILIZERS.	Laboratory No.	IN SAMPLE.			CORN AND PROXIMATE INGREDIENTS PER ACRE.						
			Corn and Cobs at Harvest.	Water-free Corn.	Water-free Corn at Harvest.	Corn and Cobs at Harvest.	Water-free Corn.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			G.	G.	%	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0, 00,	Nothing,	727	1889	934	40.95	1110	549	62.8	32.9	429.8	12.3	11.2
2,	Dissolved Bone-black,	729	2566	1352	52.69	1230	648	67.7	33.6	521.5	13.3	11.9
3,	Muriate of Potash,	731	1802	890	49.39	1230	608	63.1	29.9	492.0	12.5	10.5
6, a,	Dissolved Bone-black, Muriate of Potash, } Mixed Minerals,	733	2232	1124	50.36	1535	773	84.1	52.4	602.5	17.2	16.8
7,	Mixed Minerals, as No. 6, Nitrate of Soda, one-third ration,	735	2030	1070	52.71	2070	1091	114.6	63.0	871.8	22.3	19.3
8,	Mixed Minerals, as No. 6, Nitrate of Soda, two-thirds ration,	737	2308	1179	51.08	2510	1282	141.0	74.0	1017.3	27.0	22.7
9,	Mixed Minerals, as No. 6, Nitrate of Soda, full ration,	739	2389	1238	51.82	2880	1492	167.0	91.6	1166.0	33.4	34.0
10,	Mixed Minerals, as No. 6, Sulphate of Ammonia, one-third ration,	741	2045	1043	51.00	2050	1046	107.8	60.6	832.3	25.2	20.1
11,	Mixed Minerals, as No. 6, Sulphate of Ammonia, two-thirds ration,	743	2377	1260	53.01	2680	1421	171.4	84.1	1105.7	32.3	27.5
12,	Mixed Minerals, as No. 6, Sulphate of Ammonia, full ration,	745	2362	1295	54.83	2430	1332	153.2	85.0	1039.6	27.6	26.6
13,	Mixed Minerals, as No. 6, Dried Blood, one-third ration,	747	2266	1234	54.46	1670	909	91.5	51.8	730.7	18.2	16.8
14,	Mixed Minerals, as No. 6, Dried Blood, two-thirds ration,	749	2637	1378	52.26	2100	1098	105.5	54.8	899.9	20.4	17.4
15,	Mixed Minerals, as No. 6, Dried Blood, full ration,	751	2348	1228	52.30	2490	1302	134.2	73.6	1043.5	27.1	23.6

Water-free Corn in above samples: Minimum, 49.39 per cent.; maximum, 54.83 per cent.; average, 51.95 per cent.

TABLE 55.

Special Nitrogen Experiment of E. H. Lathrop, 1889. Proximate Ingredients in Stover per Acre.

No. of Plot.	FERTILIZERS.	Laboratory No.	IN SAMPLE.			STOVER AND PROXIMATE INGREDIENTS PER ACRE.						
			Stover at Harvest.	Water-free Stover.	Water-free Stover at Harvest.	Stover at Harvest.	Water-free Stover.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			G.	G.	%	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0, 00,	Nothing,	726	2481	1389	55.99	2000	1120	72.2	23.2	580.6	379.8	64.2
2,	Dissolved Bone-black,	728	1772	1095	61.80	2610	1613	75.6	32.8	856.5	561.5	86.6
3,	Muriate of Potash,	730	1474	760	51.97	2320	1206	53.5	21.9	671.9	392.9	65.8
6, a,	Dissolved Bone-black, Muriate of Potash, } Mixed Minerals,	732	1999	943	47.17	3305	1559	78.9	27.0	856.7	496.2	100.2
7,	Mixed Minerals, as No. 6, Nitrate of Soda, one-third ration,	734	1375	832	60.50	3090	1870	92.4	33.1	1010.6	633.9	100.0
8,	Mixed Minerals, as No. 6, Nitrate of Soda, two-thirds ration,	736	1701	1019	59.91	3170	1899	99.7	35.1	1005.4	648.9	109.9
9,	Mixed Minerals, as No. 6, Nitrate of Soda, full ration,	738	2296	1262	54.98	3110	1710	95.1	35.8	885.0	598.2	95.9
10,	Mixed Minerals, as No. 6, Sulphate of Ammonia, one-third ration,	740	1758	927	52.73	3090	1629	87.3	29.2	852.6	557.8	102.1
11,	Mixed Minerals, as No. 6, Sulphate of Ammonia, two-thirds ration,	742	1914	997	52.09	3130	1630	83.6	22.5	831.8	600.6	91.5
12,	Mixed Minerals, as No. 6, Sulphate of Ammonia, full ration,	744	2211	1111	50.25	2820	1417	91.3	28.6	723.4	492.4	81.3
13,	Mixed Minerals, as No. 6, Dried Blood, one-third ration,	746	1899	961	54.92	3410	1873	87.7	34.5	990.6	638.5	121.6
14,	Mixed Minerals, as No. 6, Dried Blood, two-thirds ration,	748	1899	1007	53.31	3420	1823	67.3	35.9	975.1	636.0	108.7
15,	Mixed Minerals, as No. 6, Dried Blood, full ration,	750	1715	940	59.01	3430	2024	92.3	42.5	1053.4	716.8	119.0

Water-free Stover in above samples: Minimum, 47.17 per cent.; maximum, 61.80 per cent.; average, 54.97 per cent.

TABLE 56.

Special Nitrogen Experiment of E. H. Lathrop, 1889. Yield and Gain or Loss in Crop per Acre.

No. of Plot.	FERTILIZERS.			YIELD PER ACRE.							GAIN (OR LOSS –) PER ACRE OVER NOTHING PLOTS.							
	Kind.	Weight per Acre.	Cost per Acre.	Harvest Weights.			Weights from Analysis.				Corn. (11 % water.)		Stover.		Corn and Stover.			
				Shelled Corn. (11 % water.)		Stover.	Corn and Stover.				From Weight at Harvest.	From Analysis.	From Weight at Harvest.	From Anal. (water-free.)	Water-free Substance.	Protein.	Fat.	Nitrogen-free Extract.
				Good.	Poor.		Water-free Sub.	Protein.	Crude Fat.	Nit.-free Ext.								
		Lbs.	$	Bu.	Bu.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0, 00,	Nothing, - - - -	—	—	3.4	7.8	2000	1669	135	56	1010	—	—	—	—	—	—	—	—
2, -	Dissolved Bone-black, -	320	4.16	8.1	5.1	2610	2261	143	66	1378	2.0	2.0	610	493	592	8	10	368
3, -	Muriate of Potash, - -	160	3.36	5.5	7.2	2320	1814	117	52	1164	1.5	1.2	320	86	145	–18	–4	154
6, a,-	Dis. Bone-black, Mixed Muriate of Potash, Mn'ls,	320 160	8.00	10.1	6.4	3305	2332	163	79	1459	5.3	4.5	1305	439	663	28	23	449
7. -	Mixed Minerals, as No. 6, Nitrate of Soda, ⅓ ration,	480 160	12.36	12.3	9.7	3090	2961	207	96	1882	10.8	10.8	1090	750	1292	72	40	872
8, -	Mixed Minerals, as No. 6, Nitrate of Soda, ⅔ ration,	480 320	16.72	14.9	11.7	3170	3181	241	109	2023	15.4	14.7	1170	779	1512	106	53	1013
9, -	Mixed Minerals, as No. 6, Nitrate of Soda, full ration,	480 480	21.08	20.2	10.9	3110	3202	262	127	2051	19.9	18.9	1110	590	1533	127	71	1041
10, -	Mixed Minerals, as No. 6, Sul. of Ammonia, ⅓ ration,	480 120	12.60	13.3	8.7	3090	2675	195	90	1685	10.8	9.9	1090	509	1006	60	34	675
11, -	Mixed Minerals, as No. 6, Sul. of Ammonia, ⅔ ration,	480 240	17.24	19.6	9.5	3130	3051	255	107	1938	17.9	17.4	1130	510	1382	120	51	928
12, -	Mixed Minerals, as No. 6, Sul. of Ammonia, full ration,	480 360	21.86	14.7	11.1	2820	2749	245	114	1763	14.6	15.7	820	297	1080	110	58	753
13, -	Mixed Minerals, as No. 6, Dried Blood, ⅓ ration, -	480 160	12.16	11.3	6.7	3410	2782	179	86	1721	6.8	7.2	1410	753	1113	44	30	711
14, -	Mixed Minerals, as No. 6, Dried Blood, ⅔ ration, -	480 320	16.32	15.4	7.4	3420	2921	173	91	1875	11.6	11.0	1420	703	1252	38	35	865
15, -	Mixed Minerals, as No. 6, Dried Blood, full ration, -	480 480	20.48	19.5	7.8	3430	3326	227	116	2097	16.1	15.1	1430	904	1657	92	60	1087

TABLE 57.

Soil Test with Fertilizers on Corn, by A. C. Blake, 1889. Composition of Water-free Substance of Corn and Stover.

No. of Plot.	FERTILIZERS.	CORN.							STOVER.						
		Laboratory No.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Water at time of Harvest.	Laboratory No.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Water in Stover at Harvest.
			%	%	%	%	%	%		%	%	%	%	%	%
0, 00,	Nothing, - - - -	753	11.06	5.27	79.80	1.98	1.89	23.22	752	7.25	2.09	52.35	32.72	5.59	38.71
A, -	Nitrate of Soda, - -	755	11.94	5.81	78.09	2.11	2.05	22.64	754	8.56	1.86	51.02	32.97	5.59	39.63
B, -	Dissolved Bone-black, -	757	11.06	5.23	79.85	2.08	1.78	24.39	756	7.69	2.03	51.76	33.00	5.52	38.64
C, -	Muriate of Potash, - -	759	11.06	5.17	80.07	1.88	1.82	24.44	758	7.06	2.02	51.78	33.22	5.92	45.86
D, -	Nitrate of Soda, - - Dissolved Bone-black, -	761	11.44	4.99	79.83	1.91	1.83	22.54	760	7.88	2.10	51.32	32.98	5.72	39.06
E. -	Nitrate of Soda, - - Muriate of Potash, - -	763	12.00	5.19	78.69	2.00	2.12	22.75	762	8.31	1.86	51.47	32.83	5.53	39.23
F, -	Dissolved Bone-black, - Muriate of Potash, - -	765	11.06	4.73	80.64	1.77	1.80	23.76	764	6.56	2.52	52.17	32.29	6.46	46.43
G, -	Nitrate of Soda, - - Dissolved Bone-black, - Muriate of Potash, - -	767	10.94	5.04	80.51	1.84	1.67	23.11	766	8.69	2.01	49.62	33.74	5.94	42.77
H, -	Plaster, - - - -	769	10.56	4.43	81.64	1.69	1.68	21.98	768	5.69	1.93	52.95	33.90	5.53	33.51
	Minimum, - - -	—	10.56	4.43	78.09	1.69	1.67	21.98	—	5.69	1.86	49.62	32.29	5.52	33.51
	Maximum, - - -	—	12.00	5.81	81.64	2.11	2.12	24.44	—	8.69	2.52	52.95	33.90	6.46	46.43
	Average, - - - -	—	11.24	5.09	79.90	1.92	1.85	23.20	—	7.52	2.05	51.61	33.07	5.75	40.43

TABLE 58.

Soil Test with Fertilizers on Corn, by A. C. Blake, 1889. Proximate Ingredients in Corn per Acre.

No. of Plot.	FERTILIZERS.	Laboratory No.	IN SAMPLE.			CORN AND PROXIMATE INGREDIENTS PER ACRE.						
			Corn and Cobs at Harvest.	Water-free Corn.	Water-free Corn at Harvest.	Corn and Cobs at Harvest.	Water-free Corn.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			G.	G.	%	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0, 00, -	Nothing,	753	1684	1048	62.23	375	234	25.9	12.4	186.7	4.6	4.4
A, - -	Nitrate of Soda,	755	2260	1408	62.30	720	448	53.5	26.0	349.8	9.5	9.2
B, - -	Dissolved Bone-black,	757	2271	1395	61.43	720	442	48.9	23.1	352.9	9.2	7.9
C, - -	Muriate of Potash,	759	1748	1048	59.96	600	360	39.9	18.6	288.2	6.8	6.5
D, - -	Nitrate of Soda, Dissolved Bone-black,	761	2000	1261	63.05	820	517	59.1	25.8	412.7	9.9	9.5
E, - -	Nitrate of Soda, Muriate of Potash,	763	1478	924	62.52	740	463	55.5	24.0	364.4	9.3	9.8
F, - -	Dissolved Bone-black, Muriate of Potash,	765	1227	751	61.21	500	306	33.9	14.5	246.7	5.4	5.5
G, - -	Nitrate of Soda, Dissolved Bone-black, Muriate of Potash,	767	2431	1534	63.10	1200	757	82.8	38.1	609.5	13.9	12.7
H, - -	Plaster,	769	1754	1125	64.14	760	487	51.5	21.6	397.6	8.2	8.1

Water-free Corn in above samples: Minimum, 59.96 per cent.; maximum, 64.14 per cent.; average, 62.22 per cent.

TABLE 59.

Soil Test with Fertilizers on Corn, by A. C. Blake, 1889. Proximate Ingredients in Stover per Acre.

No. of Plot.	Fertilizers.	Laboratory No.	In Sample.			Stover and Proximate Ingredients Per Acre.						
			Stover at Harvest.	Water-free Stover.	Water-free Stover at Harvest.	Stover at Harvest.	Water-free Stover.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			G.	G.	%	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0, 00,	Nothing,	752	2296	1407	61.29	895	549	39.8	11.5	287.5	179.6	30.6
A,	Nitrate of Soda,	754	2112	1275	60.37	1060	640	54.8	11.9	326.5	211.0	35.8
B,	Dissolved Bone-black,	756	2197	1348	61.36	1230	755	58.0	15.3	390.9	249.1	41.7
C,	Muriate of Potash,	758	2551	1381	54.14	1290	699	49.4	14.1	361.9	232.2	41.4
D,	Nitrate of Soda, Dissolved Bone-black,	760	2140	1304	60.94	1250	762	60.0	16.0	391.1	251.3	43.6
E,	Nitrate of Soda, Muriate of Potash,	762	1899	1154	60.77	1320	802	66.6	14.9	412.8	263.3	44.4
F,	Dissolved Bone-black, Muriate of Potash,	764	2268	1215	53.57	1480	793	52.0	20.0	413.7	256.1	51.2
G,	Nitrate of Soda, Dissolved Bone-black, Muriate of Potash,	766	2055	1176	57.23	1740	996	86.6	20.0	494.1	336.1	59.2
H,	Plaster,	768	1871	1244	66.49	1090	726	41.3	14.0	384.4	246.1	40.2

Water-free Stover in above samples: Minimum, 53.57 per cent.; maximum, 66.49 per cent.; average, 59.57 per cent.

TABLE 60.

Soil Test with Fertilizers on Corn, by A. C. Blake, 1889. Yield and Gain in Crop per Acre.

No. of Plot.	FERTILIZERS.			YIELD PER ACRE.						GAIN PER ACRE OVER NOTHING PLOTS.							
				Harvest Weights.		Wts. from Analysis.											
						Corn and Stover.				Corn.		Stover.		Corn and Stover.			
	Kind.	Weight per Acre.	Cost per Acre,	Shelled Corn. (11 % water.)	Stover.	Water-free Substance.	Protein.	Crude Fat.	Nitrogen-free Extract.	From Weight at Harvest.	From Analysis.	From Weight at Harvest.	From Analysis (Water-free.)	Water-free Substance.	Protein.	Fat.	Nitrogen-free Extract.
		Lbs.	$	Bu.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0, 00 -	Nothing, - - -	—	—	4.7	895	783	66	24	474	—	—	—	—	—	—	—	—
A, - -	Nitrate of Soda, - -	160	4.20	9.0	1060	1088	108	38	676	4.3	4.3	165	91	305	42	14	202
B, - -	Dissolved Bone-black, -	320	4.16	8.9	1230	1197	107	38	744	4.2	4.2	335	206	414	41	14	270
C, - -	Muriate of Potash, -	160	3.36	7.2	1290	1059	89	33	650	2.5	2.5	395	150	276	23	9	176
D, - -	Nitrate of Soda, - - Dissolved Bone-black, -	160 320	8.84	10.4	1250	1279	119	42	704	5.7	5.7	355	213	496	53	18	230
E, - -	Nitrate of Soda, - - Muriate of Potash, -	160 160	7.88	9.3	1320	1265	122	39	777	4.6	4.6	425	253	482	56	15	303
F, - -	Dissolved Bone-black, - Muriate of Potash, -	320 160	8.00	6.1	1480	1099	86	35	660	1.4	1.4	585	244	316	20	11	186
G, - -	Nitrate of Soda, - - Dissolved Bone-black, - Muriate of Potash, -	160 320 160	12.36	15.2	1740	1753	169	58	1104	10.5	10.5	845	447	970	103	34	630
H, - -	Plaster, - - -	400	120.	9.8	1090	1213	93	36	782	5.1	5.1	195	177	430	27	12	308

THE EFFECTS OF FERTILIZERS UPON THE PERCENTAGE OF PROTEIN IN THE CROPS.

Experiments of 1888. In the analysis of corn from the experiments of 1888, only perfect kernels were used. The study of the effects of the fertilizers is thereby limited to the merchantable corn and the stover. The following table gives the averages of the percentages of protein in the corn and stover from all the plots analyzed in 1888. The arrangement in the table differs from that in the field in that the plots without nitrogen are grouped in the first part, and those with nitrogen in the last part of the table. The first column gives the number of plots, and the second, the number of samples from which the averages were computed. In order to show the range in composition the minimum and maximum percentages are given :

Minimum, Maximum, and Average Percentages of Protein in Corn and Stover with different fertilizers.—One soil test and four Special Nitrogen Experiments, 1888.

	No. of plots.	No. of samples.	Corn.			Stover.		
			Min.	Max.	Av.	Min.	Max.	Av.
Without Nitrogen.			%	%	%	%	%	%
Nothing, - - - - -	10	5	11.13	13.06	11.87	4.09	10.06	7.81
Phosphoric acid, - - -	4	4	11.06	13.38	11.86	4.50	9.44	7.46
Potash, - - - - -	4	4	9.88	13.06	11.02	4.31	10.19	7.36
Mixed minerals, - - -	16	5	9.88	12.50	11.10	4.38	8.75	6.48
All the mineral plots, - -	24	13	9.88	13.38	11.31	4.31	10.19	7.05
With Nitrogen.								
Nitrogen, - - - - -	4	4	10.94	13.25	12.02	5.63	9.75	7.81
Mixed minerals + ⅓ nitrogen ration, - - - - -	12	4	10.19	12.69	11.98	6.19	8.19	7.46
Mixed minerals + ⅔ nitrogen ration, - - - - -	12	4	10.50	13.25	11.92	5.88	9.31	7.64
Mixed minerals + full nitrogen ration, - - -	12	4	11.75	14.38	12.83	7.31	11.31	8.71
All the nitrogen plots, - -	49	25	10.19	14.38	12.19	4.81	11.31	7.76

It will be noticed, from the table, in these experiments, that:—

(1). The percentage of protein in both the corn and stover from the "nothing" plots was practically the same as that from the plots supplied with nitrogen alone, and, with one exception, was higher than that from the plots to which nitrogen was added.

(2). The produce of the plots supplied with nitrogen alone was 0.75 per cent. richer in protein than that of the plots with minerals alone. On the plots with nitrogen alone the average is about the same as on those with nitrogen and mixed minerals together. As a whole, the protein in the corn and stover from the mixed mineral plots falls 0.75 per cent. below that from the nitrogen plots, and that from the phosphoric acid plots is half of one per cent. above the average of all the mineral plots.

(3). The produce of the mixed mineral plots has the lowest percentages of protein, being 0.2 to 0.5 of one per cent. below that of the average of all the minerals and 0.75 to 1.3 per cent. below that of the "nothing" plots.

In the table below the average percentages of protein in the produce of the mixed mineral plots are compared with those of the plots with mixed minerals and nitrogen in the four special nitrogen experiments of which the produce was analyzed. Those of the "nothing" plots are also given for reference:

Average Percentages of Protein in Corn and Stover on Mixed Mineral Plots, with and without Nitrogen.—Four Special Nitrogen Experiments, 1888.

	No. of Plots.	No. of Samples.	Protein in Corn.	Prot'n in Stover.
			%	%
Nothing, - - - - -	4	4	12.06	8.60
Mixed minerals, - - - -	15	4	11.10	6.48
Mixed minerals + ⅓ nitrogen ration,	12	4	11.98	7.46
Mixed minerals + ⅔ nitrogen ration,	12	4	11.92	7.64
Mixed minerals + full nitrogen ration,	12	4	12.83	8.71

It will be noticed that :—

(1). The corn on the one-third and two-third nitrogen plots contained about the same percentages of protein as that from the "nothing" plots, and that of the full nitrogen ration had three-fourths of one per cent. more.

(2). The stover from the "nothing" plots had as high a percentage of protein as that from the full nitrogen ration plots. That from the other plots had much less protein.

(3). The addition of nitrogen caused a marked increase in the percentages of protein in both the corn and stover. The percentages increase with the amount of nitrogen supplied, though the increase is more uniform in the stover than in the corn.

Experiments of 1889. In the experiments of 1889, an average sample of the whole yield of corn, both "good" and "poor," was taken for analysis.

Minimum, Maximum, and Average Percentages of Protein in Corn and Stover with different fertilizers.—One soil test and two Special Nitrogen Experiments, 1889.

	No. of plots.	No. of samples.	PROTEIN IN CORN.			PROT'N IN STOVER.		
			Min.	Max.	Av.	Min.	Max.	Av.
Without Nitrogen.			%	%	%	%	%	%
Nothing, - - - - -	6	3	11.06	12.50	11.67	6.44	7.94	7.21
Phosporic acid, - - -	3	3	10.44	13.25	11.58	4.69	9.38	7.25
Potash, - - - - -	3	3	10.19	11.06	10.55	4.44	7.06	5.71
Mixed minerals, - - -	7	3	9.69	10.94	10.50	4.63	8.69	6.13
All mineral plots, - - -	14	10	9.69	13.25	10.83	4.44	9.38	6.28
With Nitrogen.								
Nitrogen, - - - - -	2	2	11.94	12.75	12.35	8.56	9.63	9.10
Mixed minerals + 1/3 nitrogen ration, - - - - -	6	6	9.00	10.50	10.03	4.56	5.36	4.89
Mixed minerals + 2/3 nitrogen ration, - - - - -	6	6	8.94	12.06	10.32	3.69	5.25	4.64
Mixed minerals + full nitrogen ration, - - -	6	6	9.19	11.50	10.53	4.38	6.44	5.25
All nitrogen plots, - -	24	24	8.94	12.75	10.71	3.69	9.63	5.79

The percentages of protein in these samples of corn present a very different relation to the fertilizers from that of those of the samples from the 1888 experiments. Wherever the yield was light the ratio of "poor" corn to "good" was high and the percentage of protein was correspondingly high. That this high percentage was due to the presence of poor corn and not to the fertilizer seems probable, since from the few analyses that have been made in this laboratory, it would seem that immature corn (soft ears) is richer in protein than fully matured corn. If this be true,* many deductions that might be drawn from the percentages of protein in the corn of the above table would be erroneous.

The above, of course, does not apply to the stover, and the same general observations are true of the percentages of protein in the stover from the experiments of 1889 as in those of 1888, the marked exception being the low percentages of the protein in the stover from the plots supplied with mixed minerals and nitrogen in the different rations.

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*Analyses are now being undertaken of samples at hand and more samples will, we trust be collected during the next season, to test this question.

Average Percentages of Protein in Corn and Stover on Mixed Mineral Plots, with and without Nitrogen.—Two Special Nitrogen Experiments, 1889.

	Plots.	Samples.	Corn.	Stover.
Nothing, - - - - - -	4	2	11.97	7.19
Mixed minerals, - - - -	6	2	10.28	4.84
Mixed minerals + ⅓ nitrogen ration,	6	6	10.03	4.89
Mixed minerals + ⅔ nitrogen ration,	6	6	10.32	4.64
Mixed minerals + full nitrogen ration,	6	6	10.53	5.25

The ratio of "poor" corn to "good" is about the same in all of the above plots that were supplied with nitrogen, but is somewhat higher with mixed minerals and very much higher in the nitrogen plots. The same increase of percentage of protein that was observed in the experiments of 1888 by increase of nitrogen supplied, is again found here, though in this case it is more regular in the corn than in the stover. The low percentage of protein in stover from one of the two-thirds nitrogen plots makes the average of all low.

The higher percentages of the protein in the corn from the nothing and mixed mineral plots are probably due, in part at least, to the large proportion of "poor" corn in the samples. This does not, however, account for the high percentages of protein in the stover from the nothing plots.

THE EFFECTS OF FERTILIZERS UPON THE NUMBER OF POUNDS OF PROTEIN IN THE CROPS.

The samples of corn analyzed in 1889 were taken from the total yield of corn, both "good" and "poor" together, and hence it is possible to calculate the total number of pounds of the proximate constituents of the crop with greater accuracy than is possible in the experiments of 1888, where only "good" corn was analyzed. The table contains the average number of pounds of protein found in one soil test and two special nitrogen experiments of 1889, as calculated from the total yield and analyses. The amount of protein is given for corn and stover separately, and the minimum, maximum and average amounts of protein for "corn plus stover." In the last column the average increase of protein from the different plots over the "nothing" plots is given.

Pounds per acre of Protein in Corn and Stover from Plots treated with different fertilizers.— One soil test and two Special Nitrogen Experiments, 1889.

	No. of samples.	Corn.	Stover.	CORN + STOVER.			
		Average.	Average.	Minimum.	Maximum.	Average.	Average increase over nothing plots.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Without Nitrogen.							
Nothing, - - - - -	3	39	53	66	135	92	—
Phosphoric acid, - -	3	49	62	84	143	112	20
Potash, - - - - -	3	44	59	89	192	133	41
Mixed minerals, - -	3	82	76	141	169	158	66
All mineral plots, - -	9	68	66	84	192	134	42
With Nitrogen.							
Nitrogen, - - - - -	2	48	58	104	108	106	*36
Mixed minerals + ⅓ nitrogen ration, - - - - -	6	130	83	179	293	213	*108
Mixed minerals + ⅔ nitrogen ration, - - - - -	6	183	188	173	413	271	*166
Mixed minerals + full nitrogen ration, - - -	6	199	97	227	402	296	*191
All nitrogen plots, - -	25	142	82	86	413	224	*129

* Increase over the average of the "nothing" plots of the special nitrogen experiments.

It will be noticed in the above table that the increase in pounds of protein in the mixed mineral plots is practically the sum of the increase from the phosphoric acid and potash plots, and that the increase in the case of plots supplied with mixed minerals and one-third nitrogen ration was the same (approximately) as the sum of the increase from the mixed mineral and nitrogen plots, or that of all three of the plots supplied with the single ingredients. There are no data to determine whether this relation is more or less accidental or whether it is one that would hold in a series of experiments.

The following table gives the pounds of protein in the produce from the special nitrogen experiments for the nothing and mixed mineral plots, both with and without nitrogen. It will be noticed that the addition of nitrogen to the mixed minerals produced an increase in the amount of protein in excess of the increase in the crop. This was to be expected, since the increase of nitrogen in the fertilizers increases the percentage of protein.

Pounds per Acre of Protein in Corn and Stover from Mixed Mineral Plots, with and without Nitrogen.—Two Special Nitrogen Experiments, 1889.

	No. of samples.	Corn.	Stover.	Corn and Stover.			
		Average.	Average.	Minimum.	Maximum.	Average.	Average increase over nothing plots.
Nothing, - - - - -	2	46	59	74	135	105	—
Mixed minerals, - -	2	81	71	141	163	152	47
Mixed minerals + ⅓ nitrogen ration, - - - -	6	130	83	179	293	213	108
Mixed minerals + ⅔ nitrogen ration, - - - - -	6	183	188	173	413	271	166
Mixed minerals + full nitrogen ration, - - -	6	199	97	227	402	296	191

A comparison between increase of values of crops as calculated from corn and stover (estimating corn at 50 cents per bushel and stover at $8.00 per ton), and as calculated from the ingredients found by analyses is given. These last are calculated from valuations assigned by Dr. Jenkins,* and from German valuations as given by Wolff.†

The experiment of Mr. Dean is selected, as the results gave a pecuniary gain. The added cost of fertilizers was $4.38 for each one-third ration of nitrogen supplied.

Pecuniary Gain with Fertilizers as Compared with No Manure Plots.— Special Nitrogen Experiment of M. H. Dean, 1889.

	Computed from crops at harvest.	Computed from Ingredients.	
		American.*	German.†
Mixed minerals, - - - - - - -	$11.76	$12.70	$12.13
Mixed minerals + ⅓ nitrogen ration, - -	24.31	23.26	24.48
Mixed minerals + ⅔ nitrogen ration, - -	34.97	34.53	32.62
Mixed minerals + full nitrogen ration, - -	36.48	35.49	35.20

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*Conn. Station Report, 1888, p. 143. Protein 1.6 cents, fats 4.2 cents, and extractives, .96 cents per pound.

†Landw. Kal. von Mentzel u. Lengerke, 1890, p. 97. Protein 2.85 cents, fat 1.9 cents, extractives .95 cents per pound.

RELATION OF CORN TO COB AND WATER.

The following table gives the percentages of cob and corn in the partly dried samples. The average percentage of the water in the corn is about four per cent. below that found for the average* of corn in the market. It is doubtful whether the ratio between corn and cob is much changed from what it would have been if the corn had had the percentage of water usually found in commercial corn. The last two columns give the percentages of water-free (dry) corn and of cob and water in "corn in the ear" at time of harvest.

The minimum, maximum and average percentages are given first for each experiment, and finally for all the samples analyzed.

TABLE 61.

Ratio of Corn to Cob in partly dried Samples, and of Water-free Corn to Cob and Water in Sample at Harvest.

	Laboratory No.	In partly dried sample.			In sample at harvest.	
		Partly dried Cob.	Partly dried Corn.	Water in Corn.	Water-free Corn.	Cob and Water.
Soil test experiment of A. C. Blake—1888:		%	%	%	%	%
Nothing, - - - - - - -	603	17.8	82.2	9.2	55.1	44.9
Nitrate of soda, - - - - -	605	18.3	81.7	8.3	55.2	44.8
Dissolved bone-black, - - -	607	17.2	82.8	8.9	54.9	45.1
Muriate of potash, - - - - -	609	17.5	82.5	8.5	51.8	48.2
Nitrate of soda, Dissolved bone-black, - - -	611	17.2	82.8	8.7	55.4	44.6
Nitrate of soda, Muriate of potash, - - -	613	17.0	83.0	8.6	54.3	45.7
Dissolved bone-black, Muriate of potash, - - -	615	18.6	81.4	8.4	52.8	47.2
Nitrate of soda, Muriate of potash, Dissolved bone-black, - - - -	617	17.7	82.3	8.7	54.3	45.7
Minimum, - - - - - -		17.0	81.4	8.3	51.8	44.6
Maximum, - - - - - -		18.6	83.0	9.2	55.4	48.2
Average, - - - - - - -		17.7	82.3	8.7	54.2	45.8
Special nitrogen experiment of W. I. Bartholomew—1888:						
Nothing, - - - - - - -	629	18.3	81.7	9.0	45.7	54.3
Nitrate of soda, - - - - -	627	18.1	81.9	8.9	45.9	54.1
Dissolved bone-black, - - -	625	17.7	82.3	9.3	47.0	53.0
Muriate of potash, - - - - -	623	18.5	81.5	8.2	45.8	54.2
Nitrate of soda, Dissolved bone-black, - - -	621	16.2	83.8	8.8	52.2	47.8

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* Conn. Station Report, 1888.

TABLE 61.—*Continued.*

	Laboratory No.	In partly dried sample.			In sample at harvest.	
		Partly dried Cob.	Partly dried Corn.	Water in Corn.	Water-free Corn.	Cob and Water.
	%	%	%	%	%	%
Nitrate of soda, Muriate of potash,	619	17.4	82.6	9.0	48.6	51.4
Mixed minerals,	631	16.7	83.3	7.5	48.4	51.6
Mixed minerals, One-third nitrogen ration,	633	15.2	84.8	7.8	50.4	49.6
Mixed minerals, Two-thirds nitrogen ration,	635	16.4	83.6	8.9	49.4	50.6
Mixed minerals, Full nitrogen ration,	637	17.6	82.4	9.0	48.2	51.8
Minimum,		15.2	81.5	7.5	45.7	47.8
Maximum,		18.5	84.8	9.3	52.2	54.2
Average,		17.2	82.8	8.8	48.2	51.8
Special nitrogen experiment of M. H. Dean—1888:						
Nothing,	639	21.1	78.9	8.1	45.6	54.4
Nitrate of soda,	641	20.7	79.3	7.8	48.7	51.3
Dissolved bone-black,	643	19.6	80.4	8.6	47.7	52.3
Muriate of potash,	645	20.0	80.0	9.2	45.9	54.1
Nitrate of soda, Dissolved bone-black,	647	23.2	76.8	8.3	45.3	54.7
Nitrate of soda, Muriate of potash,	649	20.6	79.4	8.2	45.8	54.2
Mixed minerals,	651	18.6	81.4	8.5	49.6	50.4
Mixed minerals, One-third nitrogen ration,	653	17.4	82.6	8.5	50.7	49.3
Mixed minerals, Two-thirds nitrogen ration,	655	16.9	83.1	7.3	50.3	49.7
Mixed minerals, Full nitrogen ration,	657	16.2	83.8	8.7	51.4	48.6
Minimum,		16.2	76.8	7.3	45.3	48.7
Maximum,		23.2	83.8	9.2	51.4	54.7
Average,		19.4	80.6	8.3	48.1	51.9
Special nitrogen experiment by Station—1888:						
Nothing,	659	20.5	79.5	8.6	55.3	44.7
Mixed minerals,	661	18.9	81.1	8.3	51.5	48.5
Mixed minerals, One-third nitrogen ration,	663	20.1	79.9	8.3	50.1	49.9
Mixed minerals, Two-thirds nitrogen ration,	665	18.2	81.8	8.6	55.4	44.6
Mixed minerals, Full nitrogen ration,	667	18.4	81.6	8.1	53.0	47.0
Minimum,		18.2	79.5	8.1	50.1	44.6
Maximum,		20.5	81.8	8.6	55.4	49.9
Average,		19.2	80.8	8.4	53.1	46.9
Special nitrogen experiment of L. J. Wells—1888:						
Nothing,	669	22.8	77.2	7.4	——	——
Nitrate of soda,	671	20.3	79.7	7.8	——	——

TABLE 61.—*Continued.*

	Laboratory No.	In partly dried sample.			In sample at harvest.	
		Partly dried Cob.	Partly dried Corn.	Water in Corn.	Water-free Corn.	Cob and Water.
		%	%	%	%	%
Dissolved bone-black,	673	21.6	78.4	7.7	——	——
Muriate of potash,	675	21.8	78.2	8.2	——	——
Nitrate of soda, Dissolved bone-black,	677	20.2	79.8	8.7	——	——
Nitrate of soda, Muriate of potash,	679	17.0	83.0	8.8	——	——
Mixed minerals,	681	18.4	81.6	8.9	——	——
Mixed minerals, One-third nitrogren ration,	683	21.0	79.0	8.6	——	——
Mixed minerals, Two-thirds nitrogen ration,	685	18.7	81.3	7.4	——	——
Mixed minerals, Full nitrogen ration,	687	18.9	81.1	8.8	——	——
Minimum,		17.0	77.2	7.4	——	——
Maximum,		22.8	83.0	8.9	——	——
Average,		20.1	79.9	8.2	——	——
Special nitrogen experiment of M. H. Dean—1889:						
Nothing,	695	18.3	81.7	6.0	54.2	45.8
Nitrate of soda,	697	19.0	81.0	5.6	49.3	50.7
Dissolved bone-black,	699	21.1	78.9	6.9	49.8	50.2
Muriate of potash,	701	16.6	83.4	7.6	53.9	46.1
Nitrate of soda, Dissolved bone-black,	703	18.1	81.9	7.0	51.9	48.1
Nitrate of soda, Muriate of potash,	705	17.2	82.8	6.5	54.3	45.7
Mixed minerals,	725	15.5	84.5	7.4	56.1	43.9
Mixed minerals, Nitrate of soda, ⅓ ration,	707	15.6	84.4	7.3	56.6	43.4
Mixed minerals, Nitrate of soda, ⅔ ration,	709	14.6	85.4	6.9	57.0	43.0
Mixed minerals, Nitrate of soda, full ration,	711	14.5	85.5	6.8	56.6	43.4
Mixed minerals, Sulphate of ammonia, ⅓ ration,	713	15.6	84.4	5.9	56.0	44.0
Mixed minerals, Sulphate of ammonia, ⅔ ration,	715	15.5	84.5	7.0	55.5	44.5
Mixed minerals, Sulphate of ammonia, full ration,	717	15.5	84.5	6.7	56.1	43.9
Mixed minerals, Dried blood, ⅓ ration,	719	14.6	85.4	6.6	55.7	44.3
Mixed minerals, Dried blood, ⅔ ration,	721	15.3	84.7	6.0	56.2	43.8
Mixed minerals, Dried blood, full ration,	723	16.2	83.8	6.7	55.3	44.7
Minimum,		14.5	78.9	5.6	49.3	43.0
Maximum,		21.1	85.5	7.6	57.0	50.6
Average,		16.4	83.6	6.7	54.6	45.4

TABLE 61.—*Continued.*

	Laboratory No.	In partly dried sample.			In sample at harvest.	
		Partly dried Cob.	Partly dried Corn.	Water in Corn.	Water-free Corn.	Cob and Water.
Special nitrogen experiment of E. H. Lathrop—1889:		%	%	%	%	%
Nothing,	727	20.7	79.3	8.6	49.5	50.5
Dissolved bone-black,	729	20.3	79.7	7.7	52.7	47.3
Muriate of potash,	731	20.3	79.7	8.3	49.4	50.6
Mixed minerals,	733	19.7	80.3	7.5	50.4	49.6
Mixed minerals, Nitrate of soda, ⅓ ration,	735	19.5	80.5	8.6	52.7	47.3
Mixed minerals, Nitrate of soda, ⅔ ration,	737	19.8	80.2	8.5	51.1	48.9
Mixed minerals, Nitrate of soda, full ration,	739	18.9	81.1	9.1	51.8	48.2
Mixed minerals, Sulphate of ammonia, ⅓ ration,	741	19.5	80.5	8.4	51.0	49.0
Mixed minerals, Sulphate of ammonia, ⅔ ration,	743	18.4	81.6	9.0	53.0	47.0
Mixed minerals, Sulphate of ammonia, full ration,	745	18.2	81.8	8.9	54.8	45.2
Mixed minerals, Dried blood, ⅓ ration,	747	17.6	82.4	7.5	54.5	45.5
Mixed minerals, Dried blood, ⅔ ration,	749	19.4	80.6	6.9	52.3	47.7
Mixed minerals, Dried blood, full ration,	751	18.4	81.6	8.8	52.3	47.7
Minimum,		17.6	79.3	6.9	49.4	45.2
Maximum,		20.7	82.5	9.1	54.8	50.6
Average,		19.3	80.7	8.3	52.0	48.0
Soil test of A. C. Blake—1889:						
Nothing,	753	17.7	82.3	7.7	62.2	37.8
Nitrate of soda,	755	17.4	82.6	7.6	62.3	37.7
Dissolved bone-black,	757	16.2	83.8	8.0	61.4	38.6
Muriate of potash,	759	18.2	81.8	6.8	60.0	40.0
Nitrate of soda, Dissolved bone-black,	761	17.0	83.0	7.3	63.0	37.0
Nitrate of soda, Muriate of potash,	763	17.2	82.8	7.1	62.5	37.5
Dissolved bone-black, Muriate of potash, Nitrate of soda,	765	17.7	82.3	6.0	61.2	38.8
Dissolved bone-black, Muriate of potash,	767	16.2	83.8	8.0	63.1	36.9
Plaster,	769	16.8	83.2	7.5	64.1	35.9
Minimum,		16.2	81.8	6.0	60.0	35.9
Maximum,		18.2	83.8	8.0	64.1	40.0
Average,		17.2	82.8	7.3	62.2	37.8
The above 81 samples.						
Minimum,	5	14.5	76.8	5.6	*45.3	*35.9
Maximum,	16	23.2	84.8	9.3	*64.1	*54.7
Average,		18.2	81.8	8.0	*53.1	*46.9

*71 samples.

The seed used in the experiments of 1889 was all from the same source, but in those of 1888, the seed for the several experiments was from different sources. The variation in averages (last three lines of table) is very large. The percentage of water-free corn at harvest in the different samples varies from 45.3 per cent. to 64.1 per cent., a range of nearly 20 per cent. This means that in the one case 100 lbs. of ears would yield 45.3 lbs. of water-free corn or 50.3 lbs. of corn with average percentage of water, and in the other case 64.1 lbs. water-free or 71.3 lbs. corn with average percentage of water. Especial pains were taken to harvest the crop, from which these samples were obtained, in dry weather, and probably much greater differences would be noticed in corn harvested in the ordinary manner.

In 1889 the ratio of corn to cob at the time of harvest was obtained. The averages as found in the different experiments are given in the table below.

Percentages of Corn and Cob at time of Harvest in one Soil Test and two Special Nitrogen Experiments of 1889.

	CORN.			COB.		
	Max.	Min.	Av.	Max.	Min.	Av.
Special Nitrogen Experiment, -	70.33	78.54	75.94	21.46	29.67	24.06
Special Nitrogen Experiment, -	70.31	75.09	72.71	24.91	29.69	27.29
Soil Test Experiment, - -	79.35	82.21	81.01	17.79	20.65	18.99
Average of Above, - - -	70.33	82.21	76.03	17.79	29.69	23.97

ALBUMINOID AND NON-ALBUMINOID NITROGEN IN CORN AND STOVER FROM FIELD EXPERIMENTS.

The albuminoid nitrogen was determined in samples from three of the field experiments of 1888, by the method of Stutzer.* The method is only an approximation towards a separation of these two classes of nitrogen compounds, and as desirable and important as this separation is, the results obtained must be unsatisfactory till better methods are devised.

The results given in the table below indicate, as would be expected, a much wider range of non-albuminoid nitrogen compounds in stover than in corn. It does not appear that the fertilizers had any marked effect on the percentage of non-albuminoid nitrogen.

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*Methods of analysis of the Association of Official Agricultural Chemists, 1887, p. 67.

TABLE 62.

Total, Albuminoid, and Non-Albuminoid Nitrogen in Corn and Stover.

Number of Plot.	FERTILIZERS.	CORN.						STOVER.					
		Laboratory No.	Total Nitrogen.	Albuminoid Nitrogen.	Non-Albuminoid Nitrogen.	In 100 %.		Laboratory No.	Total Nitrogen.	Albuminoid Nitrogen.	Non-Albuminoid Nitrogen.	In 100 %.	
						Albuminoid Nitrogen.	Non-Albuminoid Nitrogen.					Albuminoid Nitrogen.	Non-Albuminoid Nitrogen.
			%	%	%	%	%		%	%	%	%	%
	Soil Test Experiment.												
0, 00, -	Nothing, - - - - - -	603	1.78	1.67	.11	93.82	6.18	604	.75	.73	.02	97.33	2.67
A, - -	Nitrate of Soda, - - - - -	605	1.75	1.69	.06	96.57	3.43	606	.90	.85	.05	94.44	5.56
B, - -	Dissolved Bone-black, - - - -	607	1.82	1.82	.00	100.00	0.00	608	.72	.72	.00	100.00	0.00
C, - -	Muriate of Potash, - - - - -	609	1.58	1.54	.04	97.47	2.53	610	.69	.67	.02	97.10	2.90
D, - -	Nitrate of Soda, - - - - - Dissolved Bone-black, - - - -	611	1.91	1.85	.06	96.86	3.14	612	.87	.83	.04	95.40	4.60
E, - -	Nitrate of Soda, - - - - - Muriate of Potash, - - - -	613	2.07	1.97	.10	95.17	4.83	614	.88	.85	.03	96.59	3.41
F, - -	Dis. Bone-black, Muriate of Potash, } Mixed Minerals, -	615	1.72	1.61	.11	93.60	6.40	616	.70	.67	.03	95.71	4.29
G, - -	Mixed Minerals, as in F, - - - Nitrate of Soda, one-third ration, - -	617	1.87	1.76	.11	94.12	5.88	618	.77	.74	.03	96.10	3.90
	Special Nitrogen Experiment.												
0, 00, -	Nothing, - - - - - -	629	2.09	1.97	.12	94.26	5.74	630	1.61	1.29	.32	80.12	19.88
1, - -	Nitrate of Soda, - - - - -	627	2.12	2.02	.10	95.28	4.72	628	1.56	1.28	.28	82.05	17.95
2, - -	Dissolved Bone-Black, - - - -	625	2.14	2.04	.10	95.33	4.67	626	1.51	1.30	.21	86.09	13.91
3, - -	Muriate of Potash, - - - - -	623	2.09	1.98	.11	94.74	5.26	624	1.63	1.39	.24	85.28	14.72

4,	Nitrate of Soda, Dissolved Bone-black,	621	2.14	2.07	.07	96.73	3.27	622	1.42	1.25	.17	88.03	11.97
5,	Nitrate of Soda, Muriate of Potash,	619	2.10	2.04	.06	97.14	2.86	620	1.49	1.23	.26	82.55	17.45
6, a, b,	Dis. Bone-black, Muriate of Potash, } Mixed Minerals,	631	2.00	1.90	.10	95.00	5.00	632	1.40	1.16	.24	82.86	17.14
7, 10, 13,	Mixed Minerals, as No. 6, One-third Nitrogen ration,	633	1.99	1.93	.06	96.98	3.02	634	1.29	1.09	.20	84.50	15.50
8, 11, 14,	Mixed Minerals, as No. 6, Two-thirds Nitrogen ration,	635	2.12	2.01	.11	94.81	5.19	636	1.49	1.24	.25	83.22	16.78
9, 12, 15,	Mixed Minerals, as No. 6, Full Nitrogen ration,	637	2.30	2.24	.06	97.39	2.61	638	1.81	1.46	.35	80.66	19.34
	Special Nitrogen Experiment.												
0, 00,	Nothing,	639	1.85	1.74	.11	94.05	5.95	640	1.32	1.08	.24	81.82	18.18
1,	Nitrate of Soda,	641	1.86	1.79	.07	96.24	3.76	642	1.13	1.04	.09	92.04	7.96
2,	Dissolved Bone-black,	643	1.77	1.64	.13	92.66	7.34	644	1.11	1.01	.10	90.99	9.01
3,	Muriate of Potash,	645	1.64	1.52	.12	92.68	7.32	646	1.14	.94	.20	82.46	17.54
4,	Nitrate of Soda, Dissolved Bone-black,	647	1.99	1.85	.14	92.96	7.04	648	1.43	1.14	.29	79.72	20.28
5,	Nitrate of Soda, Muriate of Potash,	649	1.86	1.74	.12	93.55	6.45	650	1.23	.99	.24	80.49	19.51
6, a, b,	Dis. Bone-black, Muriate of Potash, } Mixed Minerals,	651	1.58	1.51	.07	95.57	4.43	652	.98	.84	.14	85.71	14.29
7, 10, 13,	Mixed Minerals, as No. 6, One-third Nitrogen ration,	653	1.63	1.56	.07	95.71	4.29	654	.99	.86	.13	86.87	13.13
8, 11, 14,	Mixed Minerals, as No. 6, Two-thirds Nitrogen ration,	655	1.68	1.54	.14	91.67	8.33	656	.94	.84	.10	89.36	10.64
9, 12, 15,	Mixed Minerals, as No. 6, Full Nitrogen ration,	657	1.88	1.71	.17	90.96	9.04	658	1.17	.87	.30	74.36	25.64
	Minimum in above,	—	1.58	1.51	.00	90.96	0.00	—	0.69	0.67	.00	74.36	0.00
	Maximum in above,	—	2.30	2.24	.17	100.00	9.04	—	1.81	1.46	.35	100.00	25.64
	Average of above,	—	1.90	1.81	.09	95.26	4.74	—	1.18	1.02	.16	86.44	13.56

PROXIMATE COMPOSITION OF CORN AND STOVER.

Eighty-one samples of flint corn and of stover have been analyzed in connection with the field experiments. The analyses of these samples, calculated upon water-free, *i. e.*, dry substance, are given in Tables 32, 36, 40, 44, 48, 49, 53, and 57 before. The minimum, maximum, and average of each of these are given in table 63, which follows, together with the minimum, maximum, and average of the 81 samples.

For method of obtaining samples, and methods of analysis, see pages 128 and 129.

The analyses were all made by the same analysists and methods, yet the extremes in percentage composition are wide. The seed used in the field experiments of 1889 was supplied by the Station, and was all alike. It will be noticed that the extremes of composition are as wide as in the experiments of 1888 where the seed was from different sources. Indeed, the variability in amount of protein in Mr. Dean's experiment for 1889 is as great as in the whole range of all the samples.

In the harvesting of the field experiments, and especially those from which samples for analyses were to be taken, care was exercised to select a time when the crop might be as free as possible from adhering moisture. The 36 samples of corn taken during the present season contained an average of 27.08 per cent. of water, with a minimum percentage of 21.98 and a maximum of 30.80.

The great differences in composition of the stover, even when, as in the 1889 samples, the same kind of seed is used, are very noticeable and important. In some cases the percentage of protein equals that of corn. The great range indicates the great differences that may be expected in the feeding values of the stover from different fields, or even the different parts of the same field when fertilized differently.

TABLE 63.

Proximate Composition of Corn and Corn Stover, Minimum, Maximum and Average of 81 samples grown on 128 plots in 8 fields with 20 combinations of fertilizers. Calculated to water-free (dry) substance.

	Corn.						Stover.					
	Protein.	Crude Fat.	Nitrogen-free extract.	Fiber.	Ash.	Water at time of harvest.	Protein.	Crude Fat.	Nitrogen-free extract.	Fiber.	Ash.	Water at harvest.
Exper'nt of A. C. Blake, 1888, 8 samples. (See p. 132)	%	%	%	%	%		%	%	%	%	%	%
Minimum,	9.88	5.12	78.43	1.41	1.59	—	4.31	1.64	49.63	36.12	5.14	32.38
Maximum,	12.94	5.78	81.66	1.63	1.76	—	5.63	2.12	51.21	37.25	6.16	50.03
Average,	11.33	5.33	80.14	1.53	1.67	—	4.91	1.83	50.81	36.67	5.78	40.84
Expr'nt W. I. Bartholomew, 1888, 10 samples. (See p. 136)												
Minimum,	12.44	5.23	76.89	1.37	1.50	—	8.06	1.96	46.90	30.95	6.40	60.79
Maximum,	14.38	6.34	78.88	1.66	1.72	—	11.31	2.57	49.89	33.48	8.88	71.36
Average,	13.18	5.64	78.09	1.48	1.61	—	9.51	2.18	48.35	32.26	7.70	66.33
Exper'nt of M. H. Dean, 1888, 10 samples. (See p. 140)												
Minimum,	9.88	5.36	78.45	1.47	1.61	—	5.88	1.75	48.58	30.74	5.63	46.89
Maximum,	12.44	6.00	81.29	1.69	1.85	—	8.94	2.61	52.79	35.60	7.63	63.91
Average,	11.09	5.60	80.00	1.57	1.74	—	7.15	2.09	51.41	32.77	6.58	57.78
Exper'nt of the Station, 1888, 5 samples. (See p. 144)												
Minimum,	11.44	5.32	77.93	1.62	1.58	—	7.06	1.42	45.87	34.49	6.95	43.01
Maximum,	13.19	5.66	79.72	1.81	1.65	—	8.69	1.91	48.56	35.66	9.53	55.52
Average,	12.31	5.52	78.88	1.68	1.61	—	7.80	1.67	47.55	35.22	7.76	51.18
Exper'nt of L. J. Wells, 1888, 10 samples. (See p. 148)												
Minimum,	10.50	5.08	79.11	1.35	1.55	—	6.06	1.88	49.85	31.37	5.47	51.96
Maximum,	12.69	6.15	81.01	1.74	1.84	—	8.94	2.11	52.41	33.90	7.85	64.40
Average,	11.62	5.39	79.74	1.59	1.66	—	8.00	2.03	50.74	32.74	6.49	59.98
Exper'nt of M. H. Dean, 1889, 16 samples. (See p. 149)												
Minimum,	8.94	5.11	77.12	1.58	1.80	26.85	4.06	1.32	48.49	29.69	4.40	44.84
Maximum,	13.25	7.22	81.37	2.27	2.12	30.80	9.63	2.19	56.99	36.50	5.80	57.44
Average,	10.63	6.28	79.29	1.86	1.94	28.06	5.94	1.77	53.61	33.24	5.44	51.89
Exper'nt of E. H. Lathrop, 1889, 13 samples. (See p. 153)												
Minimum,	9.63	4.93	77.82	1.86	1.58	26.92	4.44	1.73	51.03	31.83	5.35	38.20
Maximum,	12.06	6.78	81.94	2.41	2.28	29.75	6.44	2.10	55.71	36.85	6.49	52.83
Average,	10.75	5.77	79.45	2.13	1.90	28.57	5.10	1.88	52.86	34.34	5.82	45.03
Exper'nt of A. C. Blake, 1889, 9 samples. (See p. 157)												
Minimum,	10.56	4.43	78.09	1.69	1.67	21.98	5.69	1.86	49.62	32.29	5.52	33.51
Maximum,	12.00	5.81	81.64	2.11	2.12	24.44	8.69	2.52	52.95	33.90	6.46	45.86
Average,	11.24	5.09	79.90	1.92	1.85	23.20	7.52	2.05	51.61	33.07	5.75	40.45
The above Eighty-one samples:—												
Minimum,	8.94	4.43	76.89	1.23	1.47	21.98*	4.06	1.32	45.87	29.69	4.40	32.38
Maximum,	13.25	7.22	81.94	2.41	2.43	30.80*	11.31	2.61	56.99	37.25	9.53	71.36
Average.	11.37	5.66	79.44	1.75	1.78	27.08*	6.84	1.94	51.34	33.62	6.26	48.11

* Average of 38 samples.

The average composition of New England grown flint corn, as found in 36 known analyses compiled by Dr. E. H. Jenkins of the Connecticut Station, is as follows:[*] Total dry matter, 87.77 per cent.; protein, 10.91 per cent.; crude fat, 4.91 per cent.; nitrogen-free extract, 69.16 per cent.; fiber, 1.37[†] per cent., and ash, 1.42 per cent. The averages of the samples analyzed here and of those compiled by Dr. Jenkins are given in the table below. In the first two columns, they are calculated to the average water content, at time of harvest, of the 38 samples procured by this Station in 1889; in the next two columns they are calculated to a water content of 11.00 per cent., the average here assumed for "air dry," *i. e.*, well-cured, corn, and in the last two, calculated to water-free (dry) substance.

Average Composition of New England grown Flint Corn.

	With 27.08 % Water "At Harvest."		With 11 % Water. "Air dry."		Water-free.	
	Average of 81 Samples here reported.	Av. of 36 Samples previously analyzed.	Average of 81 Samples here reported.	Av. of 36 Samples previously analyzed.	Average of 81 Samples here reported.	Av. of 36 Samples previously analyzed.
	%	%	%	%	%	%
Water, - - - - - -	27.08	27.08	11.00	11.00	—	—
Protein, - - - - - -	8.29	9.06	10.12	11.06	11.37	12.43
Crude Fat, - - - - -	4.13	4.08	5.04	4.98	5.66	5.59
Nitrogen-free extract, - -	57.92	57.46	70.70	70.13	79.44	78.80
Fiber, - - - - - -	1.28	1.14	1.56	1.39	1.75	1.56
Ash, - - - - - -	1.30	1.18	1.58	1.44	1.78	1.62

SUMMARY.

The especial object of this inquiry was to observe the effects of fertilizers, and especially of those containing nitrogen, upon the composition as well as the amount of the corn and stover produced. Eighty-one samples of corn, and the same number of stover, grown with 20 different fertilizing materials and mixtures on 128 plots in eight experiments on as many fields, have been analyzed. The soils were widely different, but nearly all were worn down by previous cropping. The weather was for the most part unfavorable. The produce of even the well-manured plots was generally rather small. The fertilizing materials supplied nitrogen as nitric acid in nitrate of soda,

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[*] Report of Connecticut Station, 1888, p. 92.

[†] The percentage of fiber, 1.37 per cent., is as corrected by the compiler, 2.37 per cent. having been by error printed in the original from which this is quoted.

as ammonia in sulphate of ammonia, and as organic nitrogen in dried blood; phosphoric acid in dissolved bone-black, and potash in muriate of potash. Nitrogen, phosphoric acid, and potash were applied separately, two by two, and all three together. To test the effects of nitrogen, each of the three different forms was added in three different amounts to the mixture of superphosphate and potash salt (mixed minerals). Some of the plots were left unmanured. We have, therefore, data for comparing the amount and composition of corn and stover grown without manure; with nitrogen, phosphoric acid, and potash, singly and in combination; and especially for making comparisons between the produce with the mineral fertilizers alone and that from mixtures in which the nitrogen was added in different forms and amounts to the mineral fertilizers.

It is possible that the individual samples may not exactly represent the whole produce on the plots from which they were taken. It would seem, however, that the number of trials averaged must be sufficient to make the inferences reasonably reliable for the conditions under which the experiments were made.

EFFECTS OF FERTILIZERS UPON THE PERCENTAGES AND TOTAL AMOUNT OF PROTEIN IN THE CROP.

1. Where the mineral fertilizers were used without nitrogen the percentages of protein, in both corn and stover, were less than in the produce from the unmanured crops.

2. Where nitrogenous fertilizers were used alone, or in combination with mineral fertilizers, the percentages of protein in both corn and stover were but a little above those of the produce from the unmanured plots.

3. The effects of the nitrogen is best observed in comparing the produce from the mixed minerals (superphosphate and muriate of potash) with that where nitrogen was added to the mixed minerals. The percentage of protein in the corn and stover was greater with nitrogen than without it, and in general increased with the amount of nitrogen added.

4. The addition of nitrogen in the fertilizers increased the total amount of protein in the crop, even when it did not increase the number of bushels of corn or pounds of stover per acre. Considering the value of protein for feeding, the use of nitrogenous fertilizers for corn may thus be advantageous, even if the increase of crop is apparently not enough to warrant the use of nitrogen.

5. No definite effect of fertilizers upon the percentages of albuminoid and non-albuminoid nitrogen was observed. The range of percentages of these constituents was wider in stover than in corn.

RELATION OF CORN TO COB AND TO WATER.

The percentages of corn in "corn in the ear" (corn plus cob) varied greatly in the different samples. In the 81 samples the range was from 45 to 64 per cent of water-free corn. That is, in the one case the 100 pounds of ears would yield 45 pounds of water-free corn or 50 pounds of air-dry corn (with 11 per cent. of water, an average for well-cured corn), and in the other case 64 pounds of water-free corn or 71 pounds of air-dry corn. These samples were obtained on dry days and under circumstances that would cause as little variation as possible. The variations in the percentages of corn harvested under ordinary conditions would doubtless greatly exceed these figures.

COMPOSITION OF CORN AND STOVER.

1. "Poor" or immature corn was found to contain a higher percentage of protein than "good" or merchantable corn. In the four samples of each analyzed, the percentage of protein of "poor" corn exceeded that of the "good" from the same plot by 1.00–2.25 per cent. How generally this would be the case further analyses must decide.

*2. The variations in the proximate composition of the corn and stover are very wide. This range is greatest in stover. In corn the proportions of protein varied from 8.9 per cent. to 13.3 per cent.; of crude fat from 4.4 to 7.2; of nitrogen-free extract from 76.9 to 81.9 per cent.; of fiber from 1.2 to 2.4; and of ash from 1.4 to 2.4 per cent. in the dry (water-free) substances. In stover the range of the protein was from 4.1 to 11.3 per cent.; of fat from 1.3 to 2.6; nitrogen-free extract from 45.9 to 57.0; of fiber from 27.9 to 37.3; ash, 4.4 to 9.5, on the water-free basis. The water in the samples at the time of harvest varied from 22 to 30.3 per cent. in the corn, and from 32.4 to 71.4 per cent. in the stover. In several of the experiments the same seed was used, and yet the variations in these are as large as in the others where the seed was different. And in a single experiment (by Mr. Dean in 1889) of twenty plots on a field with soil more uniform than usual, the range of variations is nearly as large as is found in looking through the whole list of experiments. This variation is very important, indicating as it does the great differences that may be expected in the nutritive value of corn and stover from different fields, and even from different parts of the same field under different treatment.**

A further and more complete discussion of these results is reserved for future publication.

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* *Especial attention is called to table 63, page 175, where the summary of the results of the analyses of the produce of the different experiments is given.*

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STORRS SCHOOL AGRICULTURAL
EXPERIMENT STATION,
STORRS, CONN.
Tolland County.

STATE OF CONNECTICUT.

THIRD ANNUAL REPORT

—OF THE—

STORRS SCHOOL

AGRICULTURAL EXPERIMENT STATION,

STORRS, CONN.

1890.

Printed by Order of the General Assembly.

MIDDLETOWN, CONN.:
PELTON & KING, PRINTERS AND BOOKBINDERS.
1891.

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—OF THE—

STORRS AGRICULTURAL SCHOOL.

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EXECUTIVE COMMITTEE.

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B. F. KOONS, STORRS,	*Principal of the School.*

TREASURER.

HENRY C. MILES, MILFORD,

STATION STAFF.

W. O. ATWATER,	*Director.*
C. S. PHELPS,	*Vice-Director.*
C. D. WOODS,	*Chemist.*
H. B. GIBSON,	*Assistant Chemist.*
C. B. LANE,	*Assistant in Farm Experiments.*

The Director has charge of the Office of Experiment Stations of the U. S. Department of Agriculture, and is able to exercise only a general supervision of the work of this Station, and is not responsible for the details of its operations or publications. In his absence, Mr. Woods serves as Acting Director.

While this Report was going through the press, Mr. Phelps was elected Professor of Agriculture in the School and Agriculturist of the Station. Mr. Woods was made Vice-Director, and Mr. Bailey Assistant Agriculturist. These changes take place April 1st. After that date the Station Staff will be:

W. O. ATWATER,	*Director.*
C. D. WOODS,	*Vice-Director and Chemist.*
C. S. PHELPS,	*Agriculturist.*
H. B. GIBSON,	*Assistant Chemist.*
E. A. BAILEY,	*Assistant Agriculturist.*
C. B. LANE,	*Assistant in Farm Experiments.*

Report of the Executive Committee.

To His Excellency Morgan G. Bulkeley,
Governor of Connecticut:

In accordance with the resolution of the General Assembly concerning the Congressional appropriation to Agricultural Experiment Stations, and an act of the General Assembly, approved March 6th, 1889, relating to the publication of reports of the Storrs School Agricultural Experiment Station, we have the honor to present herewith the Third Annual Report of that Station.

The Director, Prof. W. O. Atwater, has charge of the Office of Experiment Stations of the U. S. Department of Agriculture, and in consequence has been able to exercise only a general supervision of the work of the Station, and is not responsible for the details of its operations or publications. For his services of advice and general direction, which prior to July have been rendered the Station at a nominal salary, and since then without salary, the Executive Committee wish to express their sincere appreciation. Without underrating the work of the men to whom the details have been entrusted, and by whom they have been so well and faithfully executed, it is believed that much of the success of the Station is due to the counsel of one who has so long been a thoughtful student and investigator of the problems of agricultural science. In his position at the center of the Experiment Station movement, he is conversant with the needs and progress of agricultural science. On these accounts the services he renders the Station are of especial value, and by them it is enabled to enter upon new and important lines of work, and, even with its limited resources, to maintain a position among the best stations of the country. In his absence, the Chemist of the Station, Chas. D. Woods, has served as Acting Director.

It has been the constant aim of the Executive Committee to have as much of the Station work as practicable performed at the Storrs Agricultural School, and by farmers in different parts of the State, under the immediate direction of the Station. The erection of a Station barn, the fitting up a portion of the Station building for dairy purposes, and other gradual accumulations of appliances and facilities, all of which demand time and money for development, have in the past, and will in the future, continue to render possible an increase in the scope and amount of work that can be successfully carried out at the School. At present all of the agricultural work, including feeding experiments with milch cows, is centered there, under the immediate charge of Prof. C. S. Phelps.

The chemical and bacteriological investigations are carried out at Wesleyan University, Middletown, which gives free use of needed room and appliances in its chemical and biological laboratories. Close relation and unity of the different lines of work are established by having the Chemist spend a portion of his time at Storrs. In this way much of the disadvantage arising from having the chemical work carried out at a distance from the Station is overcome, and the Station is enabled to avail itself of the facilities offered by Wesleyan University, whereby considerable expense is saved to the Station, and it is enabled to prosecute inquiries much larger in amount and more useful in character than would otherwise be possible with its present resources.

During the winter of 1890 a barn was erected at the Station and four grade Jersey cows were purchased, for the purpose of conducting feeding experiments upon milk production. The arrangements were not completed till April—too late for entering upon experiments with winter feeding. During the spring and summer, preliminary experiments were undertaken and partial studies made of the effects of green fodders and soiling upon flow and composition of milk. Feeding experiments, with a special study of the daily fluctuations of percentages of fat in milk of cows upon the same and different feeds, are now in progress and will be continued through the year.

The Executive Committee wish to express their appreciation of the liberality and public spirit of Hon. J. W. Alsop, of Middletown, in promoting the investigations undertaken by the Station upon the acquisition of atmospheric nitrogen by plants, in giving the use of grounds for this purpose, and more recently by a gift of $500, whereby a study of the assimilation of the free or uncombined nitrogen of the atmosphere by plants is rendered possible. The gift is made through the treasury of Wesleyan University.

Mr. E. A. Bailey, who has been the efficient and valuable assistant in farm experiments since the organization of the Station, resigned the position October 1st, and Mr. C. B. Lane, graduate of the Storrs School in the class of 1890, was appointed in his stead.

The Committee refer to the accompanying report of the Treasurer for details of expenditure, and to that of the Director and his associates for the history of the work accomplished.

Respectfully submitted,

T. S. Gold,
J. M. Hubbard,
B. F. Koons,
Executive Committee.

REPORT OF THE TREASURER FOR THE FISCAL YEAR ENDING JUNE 30, 1890.

The following summary of receipts and expenditures is made out in accordance with the form recommended by the Association of American Agricultural Colleges and Experiment Stations, and approved by the United States Treasury Department:

TABULAR STATEMENT OF RECEIPTS AND EXPENDITURES.

RECEIPTS.

U. S. Treasury.	$7,500 00	
Sale of apparatus,	136 08	
Sale of books,	24 00	
Sale of office furniture,	76 50	
Sale of produce,	15 70	
Sale of mileage ticket on railroad,	27 62	
Balance from 1888–9,	1 85	
		$7,781 75

EXPENDITURES.

Salaries,	$4,745 37	
Bacteriological investigations,	124 96	
Building,	373 63	
Traveling expenses,	124 82	
Executive committee,	107 34	
Stationery,	50 71	
Postage, telegraph and telephone,	50 03	
Treasurer,	74 24	
Evaporation experiments,	16 02	
Fixtures not permanent,	16 91	
Bulletins and report,	179 57	
Library,	28 61	
Field experiments, labor,	95 88	
Field experiments, other than labor,	591 86	
Pot experiments,	18 50	
Team,	117 80	
Feeding experiments,	342 60	
Student and other labor,	170 58	
Apparatus, immediate,	87 24	
Apparatus, permanent,	58 57	
Chemicals,	26 58	
Coal, gas and oil,	259 56	
Hardware and lumber,	15 58	
Freight, express and cartage,	75 85	
Incidentals,	27 41	
Balance in Treasury,	1 53	
		$7,781 75

HENRY C. MILES,
Treasurer.

This will certify that we have examined the accounts of Henry C. Miles, Treasurer of the Storrs Agricultural School Experiment Station, for the fiscal year ending June 30, 1890, compared the vouchers therewith and find the same correct, showing a balance in said Treasurer's hands at the close of said fiscal year amounting to $1.53.

FRANK L. RODGERS, } *Auditors of*
W. CECIL DURAND, } *Public Accounts.*

MILFORD, CONN., Oct. 10, 1890.

Report of the Director.

Of the lines of experimental work in which the Station has been engaged during the past year, part are in continuation of those previously begun and reported upon in the Bulletins and Reports of the Station, while part are new and are described for the first time in this Report, or will be described in later publications. The inquiries in continuation of those already reported, are the following:

1. Co-operative field experiments with fertilizers by the Station and by farmers on their own farms in different parts of the State. These experiments are for the purpose of testing the different needs of soils and plants and the most economical ways of supplying them. The plan was adopted by the Station when the experiments of this series were begun in the season of 1888. It was based upon considerable past experience and was, in its essential forms, adopted by a convention of Experiment Station Directors held in Washington in March, 1889.

These experiments develop among farmers a spirit of inquiry and a talent for experimenting on their own farms, and help them to understand better the scientific principles they read and hear about and to test those principles in their practice. While the experimenters are learning for themselves they are teaching their neighbors, and the results of their work are published and spread abroad. Thus a class of men are being developed who unite science with practice, stand as middlemen between the Station and the farming community, get new knowledge of value and diffuse it in most useful ways.

2. In connection with the field experiments, analyses of the products have been made to study the effects of different fertilizers on maize, oats and grass. The devoting of so much labor to the making of analyses by current methods, solely to accumulate data regarding the nutritive values of the materials as feeding stuffs, might not have seemed wise. But, for the purpose for which the work was done, the results have an undoubted value. The last Report of the Station contained some extensive statistical details of the analyses. The present Report gives still

further data of this sort. They are needful to show the reasons for the conclusions which are based upon them. Those conclusions are expressed in clear, short statements which, it is hoped, may prove instructive and useful. The same remarks apply to the details and conclusions of other experiments here reported.

3. Observations on the growth of grass and forage plants in the Grass and Forage Garden of the Station and elsewhere, with especial reference to the cultivation of legumes.

4. Experiments upon the acquisition of atmospheric nitrogen by growing plants. The first positive proof that plants acquire nitrogen in large amounts from the air was brought in experiments by the writer at Wesleyan University some eight years ago. It was natural that results so opposed to the current opinion of specialists in this country and Europe should be received with hesitation, but they have since been abundantly confirmed by European investigators, who have shown the connection of microbes with the process of nitrogen absorption. Experiments by the Station have already been published in detail, in which the first results at Middletown, and the later observations elsewhere, have been still further confirmed. Arrangements are now being made for experiments for the study of the actual ways by which the plants obtain the nitrogen, and especially to test carefully the fixation of the free nitrogen of the air by the plants.

5. Observations on the value of the stubble and roots of plants as manure.

6. Meteorological observations have been made at the Station throughout the year, and the rainfall has been observed in connection with the field experiments in different parts of the State during the growing season.

7. Experimental studies of the bacteria of milk and their action. These were begun under the direction of Prof. H. W. Conn of Wesleyan University in 1888, and have been continued with interesting results. Accounts have been given in the Bulletins and Reports of the Station.

The following lines of work have been entered upon during the past year:

8. Investigations with the calorimeter upon the heats of combustion of some of the constituents of animal and vegetable products used as food for domestic animals and man. These inquiries have an especial scientific value in the present condition of the development of physical and theoretical chemistry. From the

economic standpoint, the object of these is to determine what may be called the fuel-value, *i. e.*, their relative value for yielding heat to keep the body warm and give muscular strength for work.

9. Feeding experiments with cows, to observe the changes in the quantity and quality of milk produced when the animals are fed with the same and with different foods.

10. Observations on field sampling of crops with a view of learning the sources of error. These are made in connection with the field experiments above referred to.

11. An investigation of the dietary of a boarding house in Middletown. This consists in weighings and analyses of the food actually consumed by about seventeen persons, principally mechanics at reasonably hard work and earning good wages. It has been undertaken in connection with the United States Department of Labor, by which nearly all of the expense is borne.

The prosecution of the work above outlined has, in the year ending December 31st, involved 212 determinations of the heats of combustion by the calorimeter, and analyses of 712 specimens of materials, as follows:

191 of foods and feeding stuffs.
21 of ash of plants.
336 of milk, cream and butter.
164 of plants grown in pot experiments, and of nutritive solutions used in connection with the investigation of the sources of the nitrogen of plants.

All of the analyses have been made in duplicate and many of them in triplicate.

My duties in connection with the office of Experiment Stations of the Department of Agriculture at Washington, are such as to leave but little time and energy for the Station work, and I have therefore been able during the past year to exercise only a general superintendence of its operations. Mr. Charles D. Woods, the Chemist of the Station, has served as Acting Director.

I take great pleasure in testifying to the ability, faithfulness, and efficiency with which the gentlemen who have had charge of the details of the work of the Station have discharged their duties.

W. O. ATWATER,
Director.

THE ACQUISITION OF ATMOSPHERIC NITROGEN BY PLANTS.

BY

W. O. Atwater and Chas. D. Woods.

The Annual Report of the Station for 1889 contained (pp. 11–51) a detailed account of the experiments undertaken up to December of that year upon the acquisition of nitrogen from the air by growing plants. With this was a summary of results of experiments conducted at Wesleyan University in 1881 and 1882, which brought the first positive experimental evidence that plants can obtain large quantities of nitrogen from the air.

In the reports of these earlier experiments it was urged that evidence implied, though it did not absolutely prove, that the free nitrogen of the air was fixed by the plants. The conclusions from the investigations thus referred to and from others upon the same subject were epitomized in the statement that:

"In brief, the acquisition of large quantities of atmospheric nitrogen by leguminous plants, which was demonstrated by the former experiments here and has been since confirmed by Hellriegel and others, is still further confirmed by the experiments herewith reported. These experiments in like manner confirm the observation by Hellriegel of the connection between root tubercles and the acquisition of nitrogen."

In the report of the former experiments here it was maintained that the failure of earlier experiments to bring evidence of the acquisition of nitrogen from the air may very probably be due in part to the loss of nitrogen, but more especially to the precautions for excluding compounds of nitrogen, which precautions were calculated to likewise exclude the action of microbes, electricity, or both, by aid, or at least in the presence of which the nitrogen is assimilated.

Although there remains to-day scarcely any doubt that plants utilize the free nitrogen of the air, more absolute proof that they do so is to be desired, and further study of the ways in which the nitrogen is assimilated is called for. Plans were devised for a series of experiments during the season of 1890, in which the plants should be grown in an atmosphere freed from nitrogen compounds, but on account of lack of means it was impossible to commence early enough to allow time for the needed preliminary work. A gift of $500 from Hon. J. W. Alsop of Middletown, referred to elsewhere, has made it possible to undertake this study, and work was begun in November. A greenhouse has been erected; a power air pump for forcing a current of air, and apparatus for washing the air so as to free it completely from all nitrogen compounds, have been procured; an air-tight case large enough to hold thirty pea plants in separate pots or jars has been constructed, and preliminary experiments are now in operation. If the winter's experience is successful, we hope to undertake the experiments proper during the coming spring and summer.

During the season of 1890, sand culture experiments, similar to those of 1889, were conducted with the following different species of plants:

Scarlet clover,
Incarnate clover,
Japan clover,
Alfalfa,
Yellow lupine,
Soja bean,
Red-eye bean,
Vetch,
Millet,
Buckwheat.

These species were grown in hopes that the results might give more light as to the kinds of plants that have the power of acquiring nitrogen from the air. The trials were conducted in substantially the same way as those described in the Report of the Station for 1889. The plants were grown in sea sand, washed and burned, so as to free it from all compounds of nitrogen. All of the plants were supplied with the necessary amount of plant food, with the exception of nitrogen, and to some of the plants, nitrogen was supplied in the form of calcium and potassium nitrates. Rather more than half of the plants were inoculated with infusions prepared by treating soil taken from near the roots of growing plants of the same or allied species. The early stages of growth were passed satisfactorily, but none of the plants not supplied with nitrogen got beyond the first "starvation" period, and most of the nitrogen-fed ones failed to make a good growth. Comparatively few of the plants developed root tubercles, and the tubercles that were formed were for the most part few and small. Of the inoculated plants, about one-third had no root tubercles; most of the other two-thirds had a very few small tubercles. A few plants, both inoculated and not inoculated, had a fair number of root tubercles, and these were the only ones that showed gain in nitrogen of any amount.

The experiments with alfalfa are not yet completed, as the plants made only a small growth during the summer, and the roots are being wintered over. Late in the autumn the tops were harvested and analyzed, and showed an increase in nitrogen in the case of the plants not supplied with nitrates. But the nitrogen in the tops of the nitrogen-fed plants was not sufficient to account for the difference between that supplied the plants and that found in the residual solutions, indicating, as in the other experiments, a decomposition of the nitrates.

On the whole, the season's results were negative, rather than positive. A few bean plants, with a fair number of root tubercles, gave a gain of several milligrams of nitrogen. For the most part, the nitrogen-fed plants showed a very large loss of nitrogen, probably owing to decomposition of the nitrates fed.

It is not thought that the negative results obtained with these different species of legumes indicate that these plants may not, under favorable circumstances, acquire atmospheric nitrogen; but they seem to us to imply that, while we have learned how to grow pea plants with reasonable success, we have not, as yet, learned how to grow all species of plants in such a way as to insure normal development.

ANALYSES OF FEEDING STUFFS.

By Chas. D. Woods.

In connection with the work of the Station, analyses of the following miscellaneous foods and feeding stuffs have been made. The analyses for the most part, have been in connection with the feeding experiments or the experiments upon the growth of plants, and have, in no case, been undertaken merely to increase the amount of this kind of data.

The results of the analyses calculated on water content at harvest or at time of analysis, follow the description of the samples. Frequently, for the purpose of comparison, the results are also given calculated to an arbitrary water basis. The results calculated to water-free (dry matter) basis are given in Table 1, page 25, at the end of this article.

Peas, Nos. 601, 691, and 689. At three different times during 1888 and 1889, peas were purchased for seed for use in pot experiments upon the acquisition of atmospheric nitrogen. The samples consisted of nearly perfect peas and were apparently quite free from admixture with other strains. The analyses calculated on water content at time of purchase follow:

	CHAMPION OF ENGLAND PEAS			East Hartford Early Peas. No. 689.	Average of Nos. 601, 691 and 689.
	No. 601.	No. 691.	Average of Nos. 601 and 691.		
	%	%	%	%	%
Water, - - - - -	11.55	12.58	12.07	13.74	12.62
Protein, - - - - -	27.47	28.58	28.02	25.07	27.04
Fat, - - - - -	1.57	2.08	1.82	1.10	1.58
Nitrogen-free extract, - -	50.37	50.43	50.40	54.45	51.75
Fiber, - - - - -	6.04	2.99	4.52	2.66	3.90
Ash, - - - - - -	3.00	3.34	3.17	2.98	3.11
Albuminoid nitrogen, - -	4.07	4.13	4.10	3.58	3.93
Non-albuminoid nitrogen, -	.33	.45	.39	.43	.40

Calculated to a uniform water content of 12½ %, (one-eighth water), the composition of the above samples of peas would be as follows:

	CHAMPION OF ENGLAND PEAS			East Hartford Early Peas, No. 689.	Average of Nos. 601, 691 and 689.
	No. 601.	No. 691.	Average of Nos. 601 and 691.		
	%	%	%	%	%
Water, - - - - -	12.50	12.50	12.50	12.50	12.50
Protein, - - . - -	27.15	28.60	27.88	25.43	27.06
Fat, - - - - - -	1.55	2.08	1.81	1.12	1.58
Nitrogen-free extract, - -	49.83	50.47	50.15	55.23	51.84
Fiber, - - - - -	5.99	3.00	4.50	2.70	3.90
Ash, - - - - - -	2.98	3.35	3.16	3.02	3.12

Six weeks beans, No. 693. Sample of seed purchased in Middletown in May, 1889, for use in pot experiments. The beans were all quite perfect and free from weevil.

Soja bean (Soja hispida), No. 798. Sample consisted of ripened seeds similar to those used in pot experiments in 1890. The beans were quite perfect and nearly uniform in size.

The analyses on water content at time of receipt follow:

	Six weeks Bean. (Seeds) No. 693.	Soja Bean. (Seeds) No. 798.
	%	%
Water,	11.46	8.32
Protein,	19.92	35.24
Crude fat,	1.81	20.48
Nitrogen-free extract,	60.26	25.86
Fiber,	3.25	4.84
Ash,	3.30	5.26
Albuminoid nitrogen,	2.78	5.40
Non-albuminoid nitrogen,	.41	.24

Horse bean (Vicia faba), No. 773. Vines and immature seeds. Grown in the Forage Garden of the Station in 1889. Sample taken, August 16, at which time the seeds were forming, but were immature. The small plot gave a yield at the rate of 17½ tons green crop per acre, containing nearly three tons of dry matter.

Soja bean (Soja hispida), No. 774. Vines and nearly mature seeds. Grown in the Forage Garden of the Station in 1889. Sample cut August 26, at which time the seeds were numerous and nearly grown. The yield was at the rate of 9½ tons of green crop per acre, containing 2½ tons of dry matter.

Soja bean, No. 869. Vines. Grown by the Station in 1890 for ensilage. Sown May 29. Only mineral fertilizers (phosphoric acid and potash) were applied. Throughout the season the plants were pale and made a slow growth. They had the appearance of having insufficient plant food. Harvested Sept. 24th. Sample taken when prepared for silo, Sept. 26. Four sections, comprising a little over four square rods, yielded at the rate of a little more than nine tons per acre.

Soja bean, No. 870. Vines. Grown as No. 869. A small section was left standing in the field after the crop was removed. They were slightly frosted Sept. 25th, but only a few leaves blackened and withered. Cut and sample taken Sept. 27th.

The analyses calculated on moisture content at time of cutting follow:

	Horse bean. (Vines) No. 773.	SOJA BEAN.			
		Vines and Seeds. No. 774.	Vines. No. 869.	Vines. No. 870.	Average of Nos. 869 and 870.
	%	%	%	%	%
Water, - - - - -	83.49	73.80	75.24	76.76	76.00
Protein, - - - - -	3.05	5.43	2.76	2.54	2.65
Fat, - - - - - -	.52	2.24	.63	.58	.60
Nitrogen-free extract, - -	5.89	10.68	11.31	11.20	11.26
Fiber, - - - - - -	5.48	5.17	7.84	7.11	7.48
Ash, - - - - - -	1.57	2.68	2.22	1.81	2.01

Calculated to a uniform water content of 12½% (one-eighth water), the composition of the above would be as follows:

	Horse bean. (Vines) No. 773.	SOJA BEAN.			
		Vines and Seeds. No. 774.	Vines. No. 869.	Vines. No. 870.	Average of Nos. 869 and 870.
	%	%	%	%	%
Water, - - - - -	12.50	12.50	12.50	12.50	12.50
Protein, - - - - -	16.16	18.10	9.74	9.58	9.66
Fat, - - - - - -	2.74	7.45	2.24	2.17	2.20
Nitrogen-free extract, - -	31.24	35.72	39.99	42.14	41.07
Fiber, - - - - - -	29.02	17.27	27.70	26.76	27.23
Ash, - - - - - -	8.34	8.96	7.83	6.85	7.34

Cow pea (Dolichos sinensis), No. 690. Vines. Grown by the Station in 1889. The yield was at the rate of 8 tons green crop per acre, containing about 1½ tons of dry matter. The sample was taken Sept. 28, at which time the crop was being harvested and prepared for the silo.

Cow pea, No. 772. Vines. Grown by the Station in 1889. The yield per acre was practically the same as in 1888. Sample taken September 27, when crop was being cut and put into silo.

Cow pea, Nos. 866 and 867. Vines. Grown by the Station in 1890 for ensilage. Sown May 29th. Only mineral fertilizers (phosphoric acid and potash) were applied. The plants thrived well, better than in the two previous years. Harvested Sept.

24th, and prepared for silo Sept. 26th. Five sections, comprising a little over five square rods, gave a yield at the rate of nearly eleven tons per acre, an increase of three tons over yields in previous seasons. Sample taken when cut for silo, Sept. 26th.

Cow pea, No. 868. Vines. Grown by the School in 1890. Sample taken from 16 rows in the field.

The analyses calculated on water content at harvest follow:

	COW PEA VINES.					
	No. 690.	No. 772.	No. 866.	No. 867.	No. 868.	Average of 5 Samples.
	%	%	%	%	%	%
Water,	82.08	80.15	80.93	81.81	85.95	82.18
Protein,	2.09	3.24	3.11	3.06	2.37	2.77
Crude fat,	.50	.46	.52	.51	.44	.48
Nitrogen-free ext.,	8.53	9.81	8.78	8.15	6.14	8.30
Fiber,	4.09	4.46	4.85	4.79	3.69	4.38
Ash,	2.71	1.88	1.81	1.68	1.41	1.89

Calculated to a uniform moisture content of 12½ % (one-eighth water), the composition of the above specimens of cow pea vines would be as follows:

	COW PEA VINES.					
	No. 690.	No. 772.	No. 866.	No. 867.	No. 868.	Average of 5 Samples.
	%	%	%	%	%	%
Water,	12.50	12.50	12.50	12.50	12.50	12.50
Protein,	10.23	14.27	14.27	14.77	14.77	13.66
Fat,	2.44	2.01	2.41	2.48	2.73	2.41
Nitrogen-free ext.,	41.64	43.23	40.24	39.15	38.24	40.50
Fiber,	19.99	19.68	22.27	23.02	22.99	21.59
Ash,	13.20	8.31	8.31	8.08	8.77	9.34

Vetch (Vicia sativa), No. 800. Seeds. Used for seed in pot experiments in 1890.

Yellow Lupine (Lupinus luteus), No. 799. Seeds. Used for seed in pot experiments in 1890. The analyses on water content as received follows:

	Vetch. (Seeds) No. 800.	Yellow Lupine. (Seeds) No. 799.
	%	%
Water,	11.12	9.93
Protein,	28.89	37.78
Fat,	1.31	6.69
Nitrogen-free extract,	51.56	27.01
Fiber,	4.20	14.42
Ash,	2.92	4.17
Albuminoid nitrogen,	4.07	5.59
Non-albuminoid nitrogen,	.55	.45

Vetch (Vicia sativa), Nos. 775 and 776. Vines. Grown by the Station in 1889. The two samples were taken from the same plot in the Forage Garden of the Station, August 23, at which time the plants were in full bloom. The yield was at the rate of 12 tons of green crop per acre, containing nearly 2½ tons of dry matter. The analyses calculated to water content at time of cutting are given below:

Vetch and Oats, No. 803. Vines. Grown by the Station in 1890. The seed was applied at the rate of one bushel of oats to two bushels of vetch per acre. This brought oats enough to support the vetch when cut before the oats began to ripen. Scotch vetch was used, a variety which seems to be larger and more productive than the common English vetch The proportion of oats in the green fodder was 1.3 to 1 part of vetch by weight. July 10, when the vetch was in bloom and the oats a little past bloom, a sample was taken for analysis. At this time six average square rods gave a yield at the rate of 8.6 tons per acre. The analysis calculated on water content at time of cutting, and the average of the analyses of two samples of oat fodder compiled by the Connecticut Station follow:

	VETCH IN BLOOM.			Vetch (in bloom) and Oats, No. 803.	Oat* Fodder. Average Two Samples.
	No. 775.	No. 776.	Average of Nos. 775 and 776.		
	%	%	%	%	%
Water,	81.35	78.22	79.78	80.26	74.90
Protein,	3.81	4.14	3.98	2.48	1.77
Crude fat,	.41	.41	.41	.94	.57
Nitrogen-free extract,	6.09	6.88	6.49	8.23	12.70
Fiber,	5.91	6.27	6.09	6.61	8.27
Ash,	2.43	4.08	3.25	1.48	1.79

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* As compiled by Dr. E. H. Jenkins, Conn. Station Report, 1888, p. 90.

Calculated to uniform water content of 12½ % (one-eighth water), the composition of the above would be as follows:

	VETCH IN BLOOM.			Vetch (in bloom) and Oats, No. 803.	*Oat Fodder. Average Two Samples.
	No. 775.	No. 776.	Average of Nos. 775 and 776.		
	%	%	%	%	%
Water, - - - - -	12.50	12.50	12.50	12.50	12.50
Protein, - - - -	17.86	16.62	17.24	10.99	6.17
Fat, - - - - - -	1.91	1.65	1.78	4.17	1.96
Nitrogen-free extract, - -	28.56	27.63	28.10	36.50	44.27
Fiber, - - - -	27.73	25.18	26.45	29.30	28.83
Ash, - - - - - -	11.44	16.42	13.93	6.54	6.24

* As compiled by Dr. E. H. Jenkins, Conn. Station Report, 1888, p. 90.

Clover (Trifolium pratense), Nos. 777 and 778. Grown in the Forage Garden of the Station in 1889. Seed sown in spring. Sample taken August 23, 1889, when the plants were in full bloom. Both samples from the same plot.

Clover, Nos. 779 and 780 were obtained in 1889 from the farm of Mr. Joseph Merrow of Mansfield, the second year after seeding. In bloom when samples were taken.

The average yield of the four samples was at the rate of 13 tons per acre with a moisture content of 81.50 %. This would make about three and one-half tons of clover hay to the acre. The analyses calculated to water content at harvest follow:

	RED CLOVER.						Average of Four Samples.
	SPRING SOWN.			FROM FIELD.			
	No. 777.	No. 778.	Average Nos. 777 and 778.	No. 779.	No. 780.	Average Nos. 779 and 780.	
	%	%	%	%	%	%	%
Water, - -	78.73	75.29	77.01	86.77	85.24	86.00	81.50
Protein, - -	3.83	4.34	4.09	2.30	2.50	2.40	3.25
Fat, - - -	.66	.80	.73	.39	.36	.38	.56
Nitrogen-free ext.,	8.76	9.83	9.29	5.32	5.67	5.50	7.39
Fiber, - -	5.89	7.14	6.52	3.96	4.66	4.31	5.42
Ash, - - -	2.13	2.60	2.36	1.26	1.57	1.41	1.88

Calculated to a uniform water content of 12½ % (one-eighth water), the composition of the above would be as follows:

	RED CLOVER.						Average of Four Samples.
	SPRING SOWN.			FROM FIELD.			
	No. 777.	No. 778.	Average Nos. 777 and 778.	No. 779.	No. 780.	Average Nos. 779 and 780.	
	%	%	%	%	%	%	%
Water, - -	12.50	12.50	12.50	12.50	12.50	12.50	12.50
Protein, - -	15.75	15.36	15.56	15.20	14.82	15.01	15.29
Fat, - - -	2.73	2.84	2.79	2.58	2.16	2.37	2.58
Nitrogen-free ext.,	36.05	34.79	35.42	35.18	33.57	34.38	34.90
Fiber, - - -	24.21	25.30	24.75	26.21	27.63	26.92	25.83
Ash, - - -	8.76	9.21	8.98	8.33	9.32	8.82	8.90

Lupine. During the season of 1889 the Station grew three species of lupine—the white *(Lupinus alba)*, the blue *(Lupinus hirsutus)*, and the yellow *(Lupinus luteus)*—in its Forage Garden. They were grown upon small plots and were kept free from weeds. The samples were all taken Aug. 6, at which time the plants were nearly past bloom and had small pods and immature seeds.

The analyses below are calculated on water content at harvest:

	WHITE LUPINE. Lupinus alba.			YELLOW LUPINE. Lupinus luteus.		
	No. 781.	No. 782.	Average Nos 781 & 782	No. 783.	No. 784.	Average Nos. 783 & 784
	%	%	%	%	%	%
Water, - -	85.19	85.68	85.43	89.20	89.04	89.12
Protein, - -	2.26	2.27	2.27	1.88	1.76	1.82
Crude fat, - -	.36	.33	.35	.23	.27	.25
Nitrogen-free ext.,	5.22	5.27	5.24	4.10	4.47	4.29
Fiber, - - -	5.28	4.89	5.09	3.41	3.44	3.42
Ash, - - -	1.69	1.56	1.62	1.18	1.02	1.10

	BLUE LUPINE. Lupinus hirsutus.			Average Nos. 781 to 786.
	No. 785.	No. 786.	Average Nos. 785 & 786	
	%	%	%	%
Water, - - - - - - -	86.21	87.26	86.73	87.09
Protein, - - - - - - -	1.96	1.98	1.97	2.02
Crude fat, - - - - - - -	.30	.29	.30	.30
Nitrogen-free extract, - - - - -	5.55	4.88	5.22	4.92
Fiber, - - - - - - -	4.34	4.04	4.19	4.23
Ash, - - - - - - - -	1.64	1.55	1.59	1.44

Wheat Fodder, No. 834. Grown by the Station in 1890. The sample was taken July 21, at which time the wheat was past bloom and the seeds were nearly two-thirds grown. The yield was at the rate of 7 tons per acre of green crop, containing about 1¾ tons of dry matter. The field was quite badly rusted.

Oats and Peas, No. 835. Fodder. Grown by the Station in 1890. The sample was taken from the partially cured hay. The crop was cut when the oats were just past bloom and the peas were from one-third to one-half grown.

Tall Meadow Fescue Grass (Festuca elatior), Nos. 801 and 802. Grown by the Station in its Forage Garden in 1890. Cut and sample taken June 23, when a little past full bloom. The yield was at the rate of nearly ten tons of green crop per acre, equal to about three tons of hay, containing two and one-half tons of dry matter.

The analyses, calculated to moisture content at time of cutting, follow:

	Wheat, Fodder. No. 834.	Oats and Peas, Fodder. No. 835.	TALL MEADOW FESCUE GRASS.		
			No. 801.	No. 802.	Average of Nos. 801 and 802.
	%	%	%	%	%
Water, - - - - -	76.79	28.72	75.92	74.70	75.31
Protein, - - - - -	2.55	14.17	2.03	2.14	2.09
Fat, - - - - -	.87	3.71	.81	.83	.82
Nitrogen-free extract, -	10.15	27.81	10.81	11.31	11.06
Fiber, - - - - -	8.11	20.51	8.76	9.21	8.98
Ash, - - - - -	1.53	5.08	1.67	1.81	1.74

Calculated to uniform water content of 12½ % (one-eighth water), the composition would be as follows:

	Wheat, Fodder. No. 834.	Oats and Peas, Fodder. No. 835.	TALL MEADOW FESCUE GRASS.		
			No. 801.	No. 802.	Average of Nos. 801 and 802.
	%	%	%	%	%
Water, - - - - -	12.50	12.50	12.50	12.50	12.50
Protein, - - - - -	9.63	17.40	7.39	7.39	7.39
Fat, - - - - -	3.36	4.56	2.93	2.85	2.89
Nitrogen-free extract, -	38.21	34.13	39.30	39.16	39.23
Fiber, - - - -	30.55	25.17	31.82	31.84	31.83
Ash, - - - - -	5.75	6.24	6.06	6.26	6.16

Maize, Fodder Corn, No. 864. Grown by the Station in 1890 for ensilage. Seed sown June 1st. Germinated unevenly, and the stand was very uneven. Cut Sept. 24th, and prepared for silo Sept. 25th. The kernels were not glazed at time of harvest. The yield was at the rate of twenty-two tons per acre. Sample taken at time of cutting for silo, September 25th.

Maize, Fodder Corn, No. 871. Grown as No. 864. Cut Sept. 25th. Apparently uninjured by frost of that morning. Sample taken at time of cutting.

The analyses on water content at harvest follow:

	MAIZE, FODDER CORN.			
	No. 864.	No. 865.	No. 871.	Average of Three Samples.
	%	%	%	%
Water, - - - - -	80.60	80.54	82.22	81.12
Protein, - - - - -	1.74	1.51	1.40	1.55
Fat, - - - - - -	.70	.46	.48	.55
Nitrogen-free extract, - -	10.43	10.83	9.75	10.33
Fiber, - - - - - -	5.41	5.61	5.20	5.41
Ash, - - - - - -	1.12	1.05	.95	1.04

Calculated to uniform water content of 12½ % (one-eighth water), the composition would be as follows:

	MAIZE, FODDER CORN.			
	No. 864.	No. 865.	No. 871.	Average of Three Samples.
	%	%	%	%
Water, - - - - -	12.50	12.50	12.50	12.50
Protein, - - - - -	7.82	6.78	6.89	7.16
Fat, - - - - - -	3.15	2.06	2.37	2.53
Nitrogen-free extract, - -	47.04	48.72	47.98	47.91
Fiber, - - - - - -	24.42	25.22	25.59	25.08
Ash, - - - - - -	5.07	4.72	4.67	4.82

Maize, Grain, Nos. 602 and 692. Two samples of flint corn, as perfect specimens of "seed" corn as could be procured, have been analyzed. The analyses, calculated upon moisture content at time of receipt and upon water-free substance, follow:

	AS RECEIVED.			IN WATER-FREE SUBSTANCE.		
	No. 602.	No. 692.	Average of Nos. 602 and 692.	No. 602.	No. 692.	Average of Nos. 602 and 692.
	%	%	%	%	%	%
Water, - - - - -	10.84	13.66	12.25	—	—	—
Protein, - - - - -	9.98	11.44	10.71	11.19	13.25	12.22
Crude fat, - - - - -	4.38	5.04	4.71	4.91	5.84	5.38
Nitrogen-free extract, - -	72.39	67.04	69.72	81.20	77.64	79.42
Fiber, - - - - -	1.10	1.24	1.16	1.23	1.44	1.33
Ash, - - - - - -	1.31	1.58	1.45	1.47	1.83	1.65

Buckwheat middlings, No. 962. Sample purchased for use in feeding experiments on milk production. From Platt, Barnes & Co., Rock Dale Mills, Berkshire Co., Mass. Cost $18 per ton.

The results obtained from the analysis of the sample, calculated to water content at time of receipt, follow:

	%
Water, - - - - - - - - - -	12.55
Protein, - - - - - - - - - -	24.65
Fat, - - - - - - - - - -	6.04
Nitrogen-free extract, - - - - - - - -	49.52
Fiber, - - - - - - - - - -	2.89
Ash, - - - - - - - - - -	4.35

More than 100 samples of corn and corn stover have been analyzed, and will be reported upon in another part of this Report.

TABLE I.

Proximate Composition of Fodders and Feeding Stuffs, Calculated on Water-free Substance.

	Laboratory Number.	Protein.	Fat.	Nitrogen-free extract.	Fiber.	Ash.
		%	%	%	%	%
Champion of England peas,	601	31.06	1.77	56.95	6.83	3.39
Champion of England peas,	691	32.69	2.38	57.69	3.42	3.82
Champion of England peas,—Average,	—	31.88	2.07	57.32	5.13	3.60
East Hartford Early peas,	689	29.06	1.28	63.12	3.09	3.45
Peas,—Average, 601, 691, 689,	—	30.94	1.81	59.25	4.45	3.55
Six weeks beans, seeds,	693	22.50	2.04	68.05	3.68	3.73
Horse beans, vines,	773	18.50	3.13	35.69	33.15	9.53
Soja beans, seeds,	798	38.44	22.34	28.20	5.28	5.74
Soja beans, vines and immature seeds,	774	20.69	8.53	40.82	19.75	10.21
Soja bean, vines,	869	11.13	2.56	45.70	31.66	8.95
Soja bean, vines,	870	10.94	2.48	48.19	30.58	7.81
Soja bean, vines,—Average,	—	11.03	2.52	46.95	31.12	8.38
Cow pea, vines,	690	11.69	2.79	47.59	22.84	15.09
Cow pea, vines,	772	16.31	2.30	49.40	22.49	9.50
Cow pea, vines,	866	16.31	2.75	45.99	25.45	9.50
Cow pea, vines,	867	16.88	2.82	44.73	26.31	9.26
Cow pea, vines,	868	16.88	3.12	43.71	26.27	10.02
Cow pea, vines,—Average,	—	15.61	2.76	46.28	24.67	10.68
Vetch, seeds,	800	32.50	1.47	58.02	4.73	3.28
Vetch, vines,	775	20.44	2.18	32.62	31.69	13.07
Vetch, vines,	776	19.00	1.89	31.58	28.78	18.75
Vetch, vines,—Average,	—	19.72	2.04	32.10	30.23	15.91
Vetch and oats,	803	12.56	4.76	41.72	33.48	7.48
Clover, spring sown,	777	18.00	3.12	41.20	27.67	10.01
Clover, spring sown,	778	17.56	3.25	39.76	28.91	10.52
Clover, spring sown,—Average,	—	17.78	3.19	40.48	28.29	10.26
Clover, from field,	779	17.37	2.95	40.21	29.95	9.52
Clover, from field,	780	16.94	2.47	38.36	31.58	10.65
Clover, from field,—Average,	—	17.16	2.71	39.28	30.77	10.08
Clover,—Average, 777 to 780,	—	17.47	2.95	39.88	29.53	10.17
Yellow lupine, seeds,	799	41.94	7.43	29.99	16.01	4.63
Yellow lupine, vines,	783	17.38	2.10	37.98	31.63	10.91
Yellow lupine, vines,	784	16.06	2.45	40.81	31.35	9.33
Yellow lupine, vines.—Average,	—	16.72	2.28	39.39	31.49	10.12
White lupine, vines,	781	15.25	2.47	35.19	35.67	11.42
White lupine, vines,	782	15.88	2.29	36.75	34.17	10.91
White lupine, vines,—Average,	—	15.57	2.38	35.97	34.92	11.16
Blue lupine, vines,	785	14.19	2.14	40.31	31.47	11.89
Blue lupine, vines,	786	15.56	2.31	38.29	31.66	12.18
Blue lupine, vines,—Average,	—	14.88	2.22	39.30	31.57	12.03
Lupine, vines,—Average, six samples,	—	15.73	2.29	38.22	32.66	11.10
Wheat fodder,	834	11.00	3.84	43.67	34.92	6.57
Oat and pea fodder,	835	19.88	5.21	39.01	28.77	7.13
Tall meadow fescue grass,	801	8.44	3.35	44.91	36.37	6.93
Tall meadow fescue grass,	802	8.44	3.26	44.76	36.39	7.15
Tall meadow fescue grass,—Average,	—	8.44	3.31	44.83	36.38	7.04
Fodder corn,	864	8.94	3.60	53.76	27.91	5.79
Fodder corn,	871	7.88	2.71	54.83	29.24	5.34
Fodder corn,—Average,	—	8.41	3.16	54.29	28.58	5.56
Buckwheat middlings,	962	28.19	6.91	56.62	3.31	4.97

THE PROXIMATE COMPOSITION OF "GOOD" AND OF "POOR" CORN.

BY

CHARLES D. WOODS.

In the field experiments with fertilizers upon corn, conducted by the Station, it has been customary at harvest to distinguish between the merchantable corn and the soft or small ears. The nearly perfect ears are designated as "good," and the soft ears and nubbins as "poor" corn. In all cases here reported upon, the samples for analysis have been taken from a number of ears.

In the analysis of the crop obtained in 1888, sound or perfect kernels were selected for the analyses. The results* thus obtained indicated definite relation between the amounts of nitrogen in the fertilizers applied and the percentages of protein (nitrogen multiplied by 6.25) found in the corn.

In 1889, samples were selected for analysis, so as to represent the whole yield of corn, including both "good" or sound kernels and "poor" or soft kernels. While something of the same relation was observed between the amounts of nitrogen in the fertilizers applied and the percentages of protein found in the corn, this was not so marked as in the previous year, and the percentages of protein were higher in the crop from the unmanured than in that from the fertilized plots.

In harvesting the field experiments with corn, the yield per acre of "good" or merchantable corn, and of "poor" corn consisting of soft ears and nubbins, is noted. In the analyses of the corn from the experiments of 1889, it was observed that wherever there was a light yield per acre, the ratio of "poor" corn to "good" was high, and it was also observed that the percentages of protein were correspondingly high. As it seemed probable that these high percentages were due to the presence of unripened or immature corn, and not to the fertilizer used, this study of the composition of "good" and of "poor" corn was undertaken.

In 1889, samples of "good" and of "poor" corn were taken from five, and in 1890, from four field experiments. The variety grown was flint corn, and in 1889 the seed was all from one source.

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* Report of Station for 1889, pp. 161 and 162.

The results of the analyses are given in table 2, which follows. For the sake of comparison, the results are calculated on dry or water-free substance. The left column of the table contains the name of the experimenter and the year in which the experiment was conducted :

TABLE 2.

Composition of "Good" or Merchantable Corn and of "Poor" Corn (Soft Ears and "Nubbins.") Analyses Calculated on Water-free Substance.

NAME OF EXPERIMENTER AND YEAR IN WHICH THE EXPERIMENT WAS CONDUCTED.	GOOD OR MERCHANTABLE CORN.					
	Number.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
		%	%	%	%	%
Dean, 1889, - -	770	10.13	6.94	79.13	1.67	2.13
Hinman, 1889, - -	787	11.06	5.14	80.52	1.66	1.62
Station, 1889, - -	792	10.88	5.17	80.62	1.80	1.53
Tucker, 1889, - -	793	11.50	5.27	80.32	1.62	1.29
Lathrop, 1889, - -	794	10.63	4.87	81.34	1.65	1.51
Hinman, 1890, - -	952	10.31	5.17	81.57	1.50	1.45
Peck, 1890, - -	956	11.63	5.20	80.40	1.55	1.22
Healey, 1890, - -	958	11.50	5.28	80.62	1.41	1.19
Loomis, 1890, - -	960	11.25	5.60	80.15	1.49	1.51
Average, - - -		10.99	5.40	80.52	1.60	1.49

NAME OF EXPERIMENTER AND YEAR IN WHICH THE EXPERIMENT WAS CONDUCTED.	POOR CORN (SOFT EARS AND NUBBINS).					
	Number.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
		%	%	%	%	%
Dean, 1889, - -	771	12.44	6.46	76.95	1.72	2.43
Hinman, 1889, - -	788	12.50	4.84	79.35	1.59	1.72
Station, 1889, - -	789	12.31	4.83	79.27	1.86	1.73
Tucker, 1889, - -	791	13.13	4.67	78.83	1.78	1.59
Lathrop, 1889, - -	790	11.63	4.25	80.77	1.75	1.60
Hinman, 1890, - -	953	12.06	4.89	79.74	1.66	1.65
Peck, 1890, - -	957	13.38	4.67	78.73	1.70	1.52
Healey, 1890, - -	959	12.25	5.13	79.66	1.53	1.43
Loomis, 1890, - -	961	12.81	4.99	78.88	1.57	1.75
Average, - - -		12.50	4.97	79.14	1.68	1.71

The differences in the proximate composition of "good" and "poor" corn are, so far as these samples are concerned, definite and constant. The table which follows points out these differences more clearly.

TABLE 3.

NAME OF EXPERIMENTER AND YEAR IN WHICH THE EXPERIMENT WAS CONDUCTED.	Excess of Percentages found in "Poor" over those found in "Good" Corn.			Excess of Percentages found in "Good" over those found in "Poor" Corn.	
	Protein.	Fiber.	Ash.	Fat.	Nit.-free Ext.
	%	%	%	%	%
Dean, 1889, - - -	2.31	.05	.30	.48	2.18
Hinman, 1889, - - -	1.44	−.07*	.10	.30	1.17
Station, 1889, - - -	1.43	.06	.20	.34	1.35
Tucker, 1889, - - -	1.63	.16	.30	.60	1.49
Lathrop, 1889, - - -	1.00	.10	.09	.62	.57
Hinman, 1890, - - -	1.75	.16	.20	.28	1.83
Peck, 1890, - - -	1.75	.15	.30	.53	1.67
Healey, 1890, - - -	.75	.12	.24	.15	.96
Loomis, 1890, - - -	1.56	.08	.24	.61	1.27
Average, - - - -	1.51	.08	.22	.43	1.38

* There was in this case .07 % more fiber in good than in poor corn.

CONCLUSIONS.

In Table 3 it will be noted that:

The percentage of protein in "poor" corn exceeds that in "good" by an average of 1.5 %, varying from a minimum of .75 % in Mr. Healey's experiment, to 2.3 % in Mr. Dean's.

There is very little difference in the amount of crude fiber in the two grades of corn.

The percentages of ash are .2 % greater in "poor" than in "good" corn.

There is an average of .4 % more fat or oil in the "good" than in the "poor" corn.

And the percentage of nitrogen-free extract (starch, sugar, etc.) in the "good" corn is increased by an average of about 1.4 %.

The uniformity and agreement of results obtained from the samples taken in different years from different fields would seem to warrant the conclusion that the difference in composition here noted fairly represents the difference in composition that may be expected to occur between "good" and "poor" flint corn when grown upon the same field with the same treatment.

FERTILIZING INGREDIENTS IN CROP AND IN ROOTS OF LEGUMES.

BY

CHARLES D. WOODS.

◆

Manurial Value of Leguminous Crops.

In connection with the study of the growth of legumes, in addition to the analyses for the purpose of ascertaining their proximate composition and feeding value,* the percentages of the principal constituents of plant food, nitrogen, phosphoric acid, and potash, were determined in some of the samples.

Nitrogen was determined by the method of Kjeldahl, phosphoric acid by the ammonium molybdate method, and potash by the method of Lindo as modified by Gladding, all three methods being as recommended by the Association of Official Agricultural Chemists.

The specimens were obtained by Prof. Phelps, Agriculturist, and Mr. Bailey, Assistant in Farm Experiments of the Station, with the aid of the senior class of the Storrs School and some outside labor during the summer season. A description of the samples will be found, with same laboratory number, in the analyses of feeding stuffs, pp. 15 to 24.

Table 4, which follows, contains the percentage of water-free substance (dry matter) in the crop at time of cutting, and the percentages of nitrogen, phosphoric acid, and potash in the water-free substance.

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* See this Report, pages 14 to 25.

TABLE 4.

Percentage of Fertilizing Ingredients in Specimens of Legumes. Calculated on Water-free Substance.

	Laboratory Number.	Water-free Substance at Harvest.	IN WATER-FREE SUBSTANCE.		
			Nitrogen.	Phosphoric Acid, (P_2O_5)	Potash, (K_2O)
		%	%	%	%
Cow pea, vines,	772	19.85	2.61	.58	2.00
Cow pea, vines,	866	19.07	2.61	.54	1.80
Cow pea, vines,	867	18.19	2.70	.54	1.82
Cow pea, vines, average,		19.04	2.64	.55	1.87
Soja bean, vines and seeds,	774	26.20	3.31	.84	2.18
Soja bean, vines,	869	——	1.78	.49	1.85
Soja bean, vines,	870	23.24	1.75	.49	1.58
Soja bean, vines, average,		——	1.77	.49	1.72
Horse bean, vines and immature seeds,	773	16.51	2.96	.51	2.65
Vetch, vines,	775	18.65	3.27	.82	3.66
Vetch, vines,	776	21.78	3.04	.72	3.06
Vetch, vines, average,		20.22	3.16	.77	3.36
Clover, spring sown,	777	21.27	2.88	.55	2.98
Clover, spring sown,	778	24.71	2.81	.52	2.82
Clover, spring sown, average,		22.99	2.85	.54	2.90
Clover, from field,	779	13.23	2.78	.52	3.14
Clover, from field,	780	14.76	2.71	.64	3.34
Clover, from field, average,		14.00	2.75	.53	3.24
Clover, average of 4 samples,		18.50	2.80	.54	3.07
White lupine, vines,	781	14.81	2.44	.52	2.90
White lupine, vines,	782	14.32	2.54	.50	2.81
White lupine, vines, average,		14.57	2.49	.51	2.86
Yellow lupine,	783	10.80	2.78	.57	3.15
Yellow lupine,	784	10.96	2.57	.53	2.82
Yellow lupine, average,		10.88	2.68	.55	2.99
Blue lupine, vines,	785	13.79	2.27	.59	2.76
Blue lupine, vines,	786	12.74	2.49	.61	3.24
Blue lupine, vines, average,		13.27	2.38	.60	3.00
Lupine, average of 6 samples,		12.91	2.52	.56	2.95

In Table 5, which follows, is given the weight per acre of the crop at harvest, and the pounds of dry matter, nitrogen, phosphoric acid, and potash contained in it.

The figures in the second column give the number of samples analysed from each plot or field.

TABLE 5.

Fertilizing Ingredients per Acre in Crop, in Specimens of Legumes. Weights of Crop as Harvested, of Dry Substance, and of Fertilizing Ingredients in Crop.

	No. of Samples Analysed from each Field.	Yield per Acre at Harvest.	Water-free Substance.	Nitrogen.	Phosphoric Acid. (P_2O_5.)	Potash. (K_2O.)
		Tons.	Lbs.	Lbs.	Lbs.	Lbs.
Cow pea, vines, - - - - - -	1	7.9	3136	82	18	63
Cow pea, vines, - - - - - -	2	10.9	4060	108	22	73
Cow pea, vines, average 3 samples, 2 plots,		9.4	3598	95	20	68
Soja bean, vines and seeds, - - -	1	9.5	4994	165	42	109
Soja bean, vines, - - - - - -	2	9.1	4230	75	21	73
Horse beans, vines and immature seeds,	1	17.5	5786	171	30	153
Vetch, vines, - - - - - -	2	12.0	4838	153	37	163
Clover, spring sown, - - - - -	2	12.3	5196	148	28	151
Clover, from field, - - - - -	2	10.4	2912	80	17	94
Clover, average 4 samples, 2 plots, -		11.4	4054	114	23	123
White lupine, - - - - - -	2	12.0	3481	87	18	100
Yellow lupine, - - - - - -	2	23.0	4970	133	27	149
Blue lupine, - - - - - - -	2	20.0	5342	127	32	160
Lupine, average 6 samples, 3 plots, -		18.4	4598	116	26	137

The manurial value of the legumes depends upon the large amount of plant food, especially nitrogen, in both the tops and the roots. They possess the peculiarity of acquiring large amounts of nitrogen while growing without reducing the store of nitrogen in the soil so much as many other crops (as wheat and corn) which contain far less nitrogen. Plants of this class respond readily to the application of mineral fertilizers, such as phosphates and potash salts, and very commonly to plaster and lime, while the more costly nitrogeneous fertilizers, (nitrate of soda, sulphate of ammonia, dried blood, etc.), have generally less effect upon them. The reason seems to be that they are able to obtain nitrogen for themselves, both from the air and from the soil.

One of the most important peculiarities of the legumes is their ability to acquire atmospheric nitrogen.* Many kinds of plants have been experimented with, but none outside the legumes have shown any especial power to utilize the nitrogen of the air. While it is likely that many, if not all, of the legumes have this power, it has been shown that peas, alfalfa, clover, serradella, lupine, and vetch are able to acquire large quantities of nitrogen from the air during their period of growth.

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*See Annual Report for 1889, page 11, and this Report, page 12.

The power of legumes of obtaining nitrogen from the soil seems to depend, at least in part, upon their root development. The large number of roots of many of this class of plants, and the depths to which they penetrate, make it possible for them to obtain food which is beyond the reach of other plants. It may be also due in part to their ability to utilize nitrogen compounds which are not available to certain other plants, *e. g.*, wheat, oats, grasses, etc.

The large amount of nitrogen in vetch, clover, horse and soja beans, etc. (see Table 5, above), illustrates the power of this class of plants to accumulate nitrogen in large amounts. The quantity of phosphoric acid and of potash, particularly the latter, in the crop from an acre is also considerable. When the crop is fed, four-fifths or more of the nitrogen, and a still larger proportion of the phosphoric acid, potash, and other mineral fertilizing ingredients go into the excrement, liquid and solid; if these are preserved, they make very rich manure. If the crop is ploughed under, its plant food is left for the use of succeeding crops.

FERTILIZING INGREDIENTS IN ROOTS.

Two specimens of cow pea roots and two of soja bean have been analyzed during the year. The roots were separated from the soil, as described in the Report for 1889, page 68.

The description of the samples follows:

56. *Cow Pea, Stubble and Roots.*—From Station field. Surface soil light loam, with rather above average amount of organic matter. Subsoil yellow loam, slightly adhesive, becoming gravel at depth of 22 to 24 inches. Field was in grass in 1888. Crop cut September 24th, 1890. Roots dug September 29th and 30th, and separated from soil October 1st. The nearly dry stubble and roots (about 5 per cent. water), from an area of four square feet, weighed as follows:

Stubble and roots from surface soil (8 in.),	50 grams, or	1,201 lbs. per acre.
Roots from subsoil to depth of 24 in.,	11 grams, or	264 lbs. per acre.
Stubble and roots to depth of 24 in.,	61 grams, or	1,465 lbs. per acre.

57. *Cow Pea, Stubble and Roots.*—From same field and taken at same time as No. 56. The nearly dry stubble and roots, from an area of four square feet, weighed as follows:

Stubble and roots from surface soil (8 in.), -	44 grams, or 1,057 lbs. per acre.
Roots from subsoil to depth of 24 in., - -	13 grams, or 312 lbs. per acre.
Stubble and roots to depth of 24 in., - -	57 grams, or 1,369 lbs. per acre.

58. *Soja Bean, Stubble and Roots.*—Field and soil same as in Nos. 56 and 57. Crop harvested and roots obtained at same time as No. 56. The nearly dry stubble and roots, from an area of four square feet, weighed as follows:

Stubble and roots from surface soil (10 in.), -	87 grams, or 2,089 lbs. per acre.
Roots from subsoil to depth of 24 in., - -	7 grams, or 168 lbs. per acre.
Stubble and roots to depth of 24 in., - -	94 grams, or 2,257 lbs. per acre.

59. *Soja Bean, Stubble and Roots.*—From same field and at same time as No. 58. The nearly dry stubble and roots, from an area of four square feet, weighed as follows:

Stubble and roots from surface soil (10 in.). -	85 grams, or 2,041 lbs. per acre.
Roots from subsoil to depth of 24 in., - -	7 grams, or 168 lbs. per acre.
Stubble and roots to depth of 24 in., - -	92 grams, or 2,209 lbs. per acre.

The results of the analyses are given in Table 6, which follows:

TABLE 6.

Percentage of Fertilizing Ingredients in Stubble and Roots, Calculated to Water-free Substance.

	Laboratory Number.	Water-free Substance in Sample.	IN WATER-FREE SUBSTANCE.		
			Nitrogen.	Phosphoric Acid, (P_2O_5)	Potash, (K_2O)
		%	%	%	%
Cow pea, stubble and roots, -	56	95.2	1.49	.41	.84
Cow pea, stubble and roots, -	57	95.3	1.53	.46	.89
Cow pea, stubble and roots, avg.		95.3	1.51	.44	.87
Soja bean, stubble and roots, -	58	95.6	.79	.27	.77
Soja bean, stubble and roots, -	59	95.7	.83	.24	.60
Soja bean, stubble and roots, avg.		95.7	.81	.26	.69

TABLE 7.

Amount of Roots and Stubble and Valuable Ingredients left in One Acre, with Valuable Ingredients in Manures, for Comparison.

KIND OF PLANT AND PORTION ANALYZED.	Laboratory Number.	Roots and Stubble (water-free)	Nitrogen.	Phosphoric Acid (P_2O_5)	Potash, (K_2O)
		Lbs.	Lbs.	Lbs.	Lbs.
Cow pea, stubble and roots pulled with stubble,	29	711	10.0	2.7	5.3
Cow pea, stubble and roots to depth of 3 feet,	30	1095	14.5	2.8	6.4
Cow pea, stubble and roots to depth of 28 in,,	52	1969	27.4	7.4	16.5
Cow pea, stubble and roots to depth of 28 in.,	53	1904	25.9	7.5	20.6
Cow pea, stubble and roots to depth of 24 in.,	56	1393	20.7	5.7	11.7
Cow pea, stubble and roots to depth of 24 in.,	57	1304	20.0	6.0	11.6
Average of Nos. 30, 52, 53, 56, and 57, -	—	1533	21.7	5.9	13.4
Soja bean, stubble and roots to depth of 22 in.,	47	701	8.6	2.2	5.7
Soja bean, stubble and roots to depth of 24 in.,	58	2158	17.1	5.8	16.6
Soja bean, stubble and roots to depth of 24 in.,	59	2113	17.5	5.1	12.7
Average of Nos. 47, 58, and 59, - -	—	1657	14.4	4.4	11.7
Horse bean, stubble and roots to depth of 22 in.,	46	1759	31.8	6.1	19.5
Vetch, stubble and roots to depth of 22 in., -	48	1401	27.1	7.2	15.9
Vetch, stubble and roots to depth of 22 in., -	49	1555	27.2	7.2	27.7
Average of Nos. 48 and 49, - - -	—	1478	27.2	7.2	21.8
Clover, stubble and roots to depth of 6 in., -	36	2638	55.1	13.7	42.3
Clover, stubble and roots to depth of 6 in., -	38	955	18.0	7.6	8.4
Average of Nos. 36 and 38, - - -	—	1797	36.6	10.7	25.4
Clover, roots below 6 in. to depth of 3 feet, -	37	268	5.1	1.4	3.1
Clover, roots below 6 in. to depth of 3 feet, -	39	410	4.8	1.4	3.0
Average of Nos. 37 and 39, - - -	—	339	5.0	1.4	3.1
Clover, stubble and total roots to depth of 3 feet, Nos. 36 and 37, - - -	—	2906	60.2	15.1	45.4
Clover, stubble and total roots to depth of 3 feet, Nos. 38 and 39, - - -	—	1365	22.8	9.0	11.4
Average of last two, - - - -	—	2136	41.5	12.1	28.4
Clover, stubble and roots to depth of 2 feet, -	50	1743	38.7	9.9	26.2
Clover, stubble and roots to depth of 2 feet, -	51	2692	55.4	16.1	45.9
Average of Nos. 50 and 51, - - -	—	2218	47.1	13.0	36.1
Clover, total roots and stubble, average of above 4 samples, - - - - -	—	2177	44.3	12.5	32.2
White lupine, stubble and roots to depth of 30 in., - - - - - - -	44	962	9.3	1.8	11.6
White lupine, stubble and roots to depth of 30 in., - - - - - - -	45	1034	11.0	1.9	10.7
Average of Nos. 44 and 45, - - -	—	998	10.2	1.9	11.2
Blue lupine, stubble and roots to depth of 30 in.,	42	1256	10.7	2.9	12.5
Blue lupine, stubble and roots to depth of 30 in.,	43	1483	11.9	3.1	25.5
Average of Nos. 42 and 43, - - -	—	1370	11.3	3.0	19.0
Yellow lupine, stubble and roots to depth of 30 in., - . - - - - -	40	1429	15.7	4.9	23.4
Yellow lupine, stubble and roots to depth of 30 in., - - - - - - -	41	1355	16.5	6.0	20.0
Average of Nos. 40 and 41, - - -	—	1392	16.1	5.5	21.7
Lupine, stubble and roots, average 6 samples,	—	1253	12.5	3.1	17.3
Fertilizers.		Fert'zs			
Rich stable manure,* - - - - -	—	2000	10	10	8
Nitrate of soda, - - - - - -	—	100	16	—	—
Dissolved bone-black, - - - - -	—	100	—	16	—
Ground bone,* - - - - - -	—	100	3	22	—
Muriate of potash, - - - - -	—	100	—	—	50

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* Analyses taken from Farmers' Annual, 1882. Jenkins and Armsby.

Table 7, on the preceding page, contains the pounds per acre of the valuable ingredients of plant food contained in the sample of roots herewith reported upon, and also the results of the work upon roots of legumes reported upon in 1889:

As might be expected, the amount of roots and stubble vary with different crops and even with the same kind of crop under different circumstances. Although the ratio between the amounts of roots and of tops is extremely variable, still it is probably true in general that the greater the amount of the crop of a given plant the greater will be the amount of roots and stubble left behind.

In the above table it will be noted that clover leaves a large amount of plant food behind in its roots after the crop is harvested, and that many of the other legumes leave considerable amounts. Comparison with the amounts of plant food (given at the end of the table) furnished by different standard fertilizers, will aid in appreciating the value of the plant food thus left behind in the soil.

When the stubble is turned under, both it and the roots decompose, and their manurial ingredients become more or less speedily and completely available for succeeding crops. The crop that leaves a large amount of these materials in and upon the soil after harvest adds much to the next year's store of plant food, and hence to the fertility of the soil.

GREEN MANURING.

It is generally better economy to feed a crop of such plants as legumes and carefully save the manure, and thus return the larger portion of the manurial matters to the land, than to plow it under. Still, there are some crops, as lupines, that may at times be used to good advantage for green manure, and circumstances may be such as to warrant the use of other and more valuable crops for this purpose.

In Table 8, which follows, the pounds of nitrogen, potash, and phosphoric acid furnished by a crop of legumes, as grown by the Station, are given. The yield per acre is assumed to be as found in the experimental plots. Under each fertilizing constituent is given the number of pounds per acre removed in the crop, the number of pounds left behind in roots and stubble, and the total found in crop, stubble and roots.

TABLE 8.

Fertilizing Ingredients in Crop and Roots per Acre in some Legumes, and Fertilizing Ingredients in Manures for Comparison.

	NITROGEN.			PHOSPH'C ACID (P_2O_5)			POTASH. (K_2O)		
	In Crop.	In Roots, etc.	Total.	In Crop.	In Roots, etc.	Total.	In Crop.	In Roots, etc.	Total.
Horse bean, - - - -	171	32	203	30	6	36	153	20	173
Soja bean, vines and seeds, -	165	9	174	42	2	44	109	6	115
Soja bean, vines, - - -	75	13	88	21	5	26	73	14	87
Cow pea, vines, - - -	95	22	117	20	6	26	68	13	81
Vetch, vines, - - - -	153	27	180	37	7	44	163	22	185
White lupine, vines, - -	87	10	97	18	2	20	100	11	111
Yellow lupine, vines, - -	133	16	149	27	6	33	149	22	169
Blue lupine, vines, - - -	127	11	138	32	3	35	160	19	179
Red clover, vines, - - -	138	44	152	32	13	45	152	32	184
FERTILIZERS.									—
One ton rich stable manure, -			10			10			8
100 pounds nitrate of soda, -			16			—			—
100 pounds dissolved bone-black,			—			16			—
100 pounds ground bone, -			3			22			50
100 pounds muriate potash, -			—			—			

The value of legumes for green manuring is more clearly seen in the above table, if a comparison be made between the amount of plant food that is turned under in the crop and that contained in a given weight of standard fertilizers. For example, the white lupine grown by the Station (see Table 8), though yielding an unusually small crop, contained per acre in its tops and roots as much nitrogen as 600 pounds of nitrate of soda, as much potash as 200 pounds of muriate of potash, and more phosphoric acid than 100 pounds of dissolved bone-black.

While nitrogen in the form of decaying organic matter is not so readily available as that of nitrate of soda, and for immediate use wouid not be as valuable, yet it stays longer in the soil and its effect is more enduring. The use of such plants on light soils, naturally deficient in organic matter and in nitrogen, for green manuring, is a subject worthy of careful consideration and trial.

FODDER CROPS FOR SOILING AND ENSILAGE.

BY

C. S. PHELPS.

Where farmers are obliged to feed their stock in the stable altogether, or have only a limited amount of pasturage, it is frequently desirable to grow fodder crops for use during the summer months. In such cases it is important to be able to select plants that will give a succession of suitable fodder in the best stage of growth for feeding at the time when it is wanted. Grass and other like fodders are generally considered to contain the largest amount of digestible food materials when in blossom. By planting, in successive periods, small areas of the same crop, or different crops reaching the flowering period about together, the fodder will reach the best feeding stage at different times. In this way a large amount of fodder can be grown in a better condition for use than if large areas are sown at one time.

During 1890, the Station grew a succession of fodder crops which were used in feeding milch cows. These green fodders were fed from the first week in June until November 12th. The succession consisted of wheat-fodder, clover, oats and vetch, oats and peas, clover rowen, corn-fodder, rowen, barley and peas, and barley fodder. Those that were under direct experiment by the Station are reported upon below.

WHEAT-FODDER.

About one-half acre of land, that had been used in growing cow peas during 1889, was ploughed and prepared for wheat the first week in October. The Clawson variety was sown October 7th, at the rate of one and one-half bushels per acre. The soil of this field is a gravelly loam and the subsoil slightly compact and clayey. The land slopes quite rapidly to the west.

The crop wintered well. April 21st, it was noted that the wheat was pale yellow in color and appeared to be making slow growth. Eighty pounds of nitrate of soda was applied, and in a few days the crop appeared darker colored and began to improve rapidly. May 26th, it was noticed that the fodder was slightly yellow. Forty pounds of nitrate of soda was applied with the same effects as noted above.

The wheat was used for feeding from June 7th to June 23d. When the feeding began the growth of fodder appeared quite heavy and the heads were about half grown. About June 20th, the crop was attacked by rust. The leaves soon turned yellow, the stems became hard and woody, and the fodder was not well eaten. June 16th, when the wheat was in bloom, three average square rods gave a yield at the rate of 7.1 tons of green crop per acre. For chemical analysis, see pages 22 and 23.

If this crop is sown during the early part of September, the wheat will be ready for use about May 25th, and will furnish good fodder for two or three weeks. Wheat seems to make a much better soiling crop than rye. It can be fed during a longer period of time and contains a much larger proportion of leaf growth. Rye rapidly becomes hard and woody after it has reached the best feeding stage, and the stems are apt to be rejected by stock.

ENSILAGE CORN.

The field used in growing ensilage corn comprises about one-half acre. It produced a crop of oat fodder in 1889, and had a light application of fertilizer that year. The land is nearly level, with a clayey loam soil, and is quite moist in places. About 9 tons of fresh stable manure was applied to this area, and ploughed in a few days before planting. The land was ploughed and prepared for the seed May 30th and June 1st, the field being check-rowed 3.3 feet each way. Four kernels of Breck's Boston market variety were planted in each hill. Just before planting, dissolved bone-black, at the rate of 320 lbs. per acre, was applied in the hill to one-half of the field, and Thomas' slag to the other half at the same rate. The soil was kept free from weeds almost entirely by the use of the cultivator. Notes taken August 21st, showed that much of the corn was in blossom on the half where the bone-black was applied. Tassels on the other half, where slag was applied, were about three-fourths grown, and stalks 6 to 10 inches shorter. The corn advanced toward maturity slowly, and had to be cut before the kernels were glazed, in order to prevent damage from frost.

The crop was cut September 24th, and left in small piles until the afternoon of the 25th, when it was hauled, cut into half-inch lengths, and packed into the silo. Owing to the unevenness of the field, and the difficulty of weighing the entire crop, no test, by weighing, was made of the relative effect of the bone-black and slag. The portion of the crop receiving bone-black, however, appeared more advanced throughout the season. Six average square rods from the entire field gave a yield at the rate of 22 tons per acre. The yield, even with a partial stand, was more than an average one. The proportion of ears and leaves was noticeably large. The crop had the advantage of more sunlight than it would have had in drills, and horse power could be more effectually applied in cultivating the crop. For chemical analysis, see page 23.

BARLEY AND PEA FODDER.

The area of land used in growing this fodder was the same as that used for wheat, and is described above. The land was prepared for seeding the second week in August. A fertilizing mixture, consisting of pulverized tankage, blood, bone and meat, and muriate of potash was applied, at the rate of 720 lbs. per acre. This supplied about 40 pounds of nitrogen, 80 pounds of potash, and 40 to 50 pounds of phosphoric acid per acre. The land (one-half acre) was seeded August 11th, with 24 quarts of barley and 1 bushel of Canada peas. The weather remained quite dry for two weeks after sowing, and many of the peas failed to germinate. August 22d, it was observed that the barley showed a good growth, but the mixture of peas seemed quite uneven. Feeding began October 1st, at which time the fodder appeared to be about three-fourths grown. October 29th, six average square rods gave a yield at the rate of 7.2 tons per acre. The proportion of peas seemed small, but both the barley and peas had made a vigorous growth, and were well eaten by stock.

At the same time with the above, the field from which oats and vetch, and oats and peas were fed during July, was sown to barley alone. The seed was sown at the rate of two bushels per acre. These two fodders, barley and peas, and barley, furnished valuable feed for milch cows, from October 1st to November 12th. Several severe frosts did not seem to damage the crop. If peas are sown with barley, a fodder richer in protein can be obtained than from barley alone. We would recommend farmers to try this mixture, and if the peas are covered deeply, a uniform and heavy growth ought to be obtained. It makes a valuable supplement to pasturage at a time when most other fodders would be killed by frost.

FODDER CROPS ON ORCHARD FIELD.

An area of land, comprising about one and one-fourth acres, which had been set to peach and pear trees during the spring of 1889, was ploughed during November of that year, preparatory for use in growing fodder crops, during 1890.

The soil is a medium heavy loam, warm and well drained, and the subsoil is a yellow, rather compact clayey loam. The field has a gentle slope to the south and west. This area was used in growing oats and vetch, oats and peas, soja beans, and cow peas.

OATS AND VETCH.

About one-third of an acre of the above field was sown, April 16th, with common Western oats and Scotch vetch. The seeding was at the rate of two bushels of oats and three of vetch per acre. A fertilizer, consisting of dried blood, nitrate of soda, pulverized bone and meat, dissolved bone-black, and muriate of potash, was used at the rate of 800 lbs. per acre. The materials were mixed in such proportions as to supply 45 lbs. of nitrogen, 60 lbs. of phosphoric acid, and 75 lbs. of potash per acre. The fertilizer was applied and harrowed in just previous to seeding.

The seed germinated well, and gave a good stand of both oats and vetch. Early in June the oats were attacked by rust, but were only slightly injured, and improved rapidly toward the close of the month. The vetch began to blossom July 2d, and the oats were nearly headed out. On July 12th, the vetch was generally in blossom, and the oats were beginning to form seed. At this date, the fodder appeared in the best condition for feeding. The yield from six average square rods, was at the rate of 8.6 tons of green crop per acre. In an average sample of 30 lbs., the proportion of oats to vetch in the green crop was found to be 1.3 of oats to 1 of vetch. The chemical analysis is given on page

19. The fodder was fed from July 4th to July 24th, but after July 18th the oats had become badly dried, owing to continued dry weather, and were not well eaten.

Scotch vetch is a larger variety and a more vigorous grower than the common English vetch, and it remained green and succulent after the oats had matured. Where small areas are sown successively, oats and vetch sown in about the above proportions make one of the best soiling crops for July feeding.

OATS AND PEAS.

This crop was sown May 12th, on about one-fourth of an acre, adjoining the oats and vetch, and the same fertilizing mixture was used. The small Canada pea was sown at the rate of three bushels per acre, with two bushels of Western oats. The peas and oats germinated well and made rapid growth. Early in June the oats rusted slightly, but improved rapidly later in the month. On July 8th, the peas were generally in bloom, and the oat-heads were one-half to two-thirds grown. On July 18th, the crop was cut and cured for hay. The proportion of oats did not seem to be sufficient to support the peas, and the crop became quite badly lodged. For this reason the crop was poorly cut by the mower, and the yield per acre was not taken. Canada peas make a more rapid growth than vetch, and from our experience this season (1890), we believe they should be sown and fed before the vetch. The chemical analysis is given on page 19.

SOJA BEANS AND COW PEAS.

The land upon which these fodder plants were grown was prepared for use the last week in May. The seed was sown May 29th, in drills two feet ten inches apart, at the rate of one bushel per acre. Mineral fertilizers, consisting of 320 lbs. bone-black and 160 lbs. muriate of potash per acre, were used on all of the field, except a portion of the area sown to soja beans, where the amount was increased to 800 lbs. of this mixture per acre.

SOJA BEANS.

The seed germinated quite slowly and unevenly. June 14th, it was noted that the drills were poorly stocked, especially where the larger quantities of fertilizer were applied. The plants made a rather slow growth, and throughout the season the foliage appeared of a pale yellow color. By the middle of September, the plants had reached a height of three and one-half to four feet. They were not branched, nor very leafy, and the stems were hard and woody. The best growth was obtained where 480 lbs. per acre of mineral fertilizer was applied. September 23d, the soja beans were pale colored, and not as leafy nor succulent as the cow peas. Four small sections, cut on the above date, gave a yield at the rate of 9.1 tons per acre. The crop was cut September 24th, and left in small piles to wilt. On the 26th, it was cut into about one inch lengths and packed in the silo. For chemical analysis, see pages 16 and 17.

COW PEAS.

The cow peas germinated slowly, but evenly. The growth was slow for the first two or three weeks, but the warm weather during the latter part of June hastened their development. The growth was quite rapid during the summer, and the foliage remained dark colored. By August 20th, the ground between the drills was entirely covered by the vines. The cow pea fodder was cut and harvested at the same time, and in the same way as the soja beans. Notes were taken the day before harvest, and the peas were observed to have made a spreading, twining growth, and reached an average height of about two feet. The lower leaves had become slightly yellow, and had dropped off to some extent, but the stems were soft, and the fodder, as a whole, much more succulent than the soja beans. Five small sections, taken from different parts of the field, gave an average yield at the rate of 10.9 tons per acre. For chemical analysis, see pages 17 and 18.

Cow peas have been grown by the Station for the past three years with fair success. The plant seems to thrive well without the use of fertilizers containing nitrogen. The above yield (10.9 tons of green crop) was obtained from the use of mineral fertilizers, costing at retail about $8 per acre. During the past three years considerable quantities of the seed have been sent out by the Station, for trial by farmers in various parts of the state. Extracts from the reports received are given herewith.

Daniels Brothers, of Middletown, have grown and fed the crop for the past two years. The following is taken from their report:

> Think the cow peas make excellent fodder for milch cows; believe we can get as much feed to the acre as from fodder corn, on the same soil. Our herd of

eighteen to twenty cows gave from ten to twelve quarts more milk daily when fed on cow peas for one week than they did when fed on corn fodder for the same time. Three average square rods gave a yield at the rate of 6.3 tons per acre. Fish and potash was applied at the rate of 600 lbs. per acre.

Mr. H. H. Hubbard, of Middletown, gives the following as his experience:

> The cows did well on the fodder; I think better than on corn. Milch cows ate the peas freely, with one exception. The crop was grown on rich soil after onions, and a very heavy yield was obtained. The chief difficulty was in harvesting, owing to the plants being closely intertwined.

Mr. S. T. Kimball, of Ellington, has grown them both for feeding green and for ploughing under, and says:

> The soil is dry, light and sandy loam, and the subsoil nearly clear sand. No crop was grown on the land the previous year, and there was not enough goodness in the soil to form a sward for pasturing. The seed was sown both broadcast and in drills two feet apart. Milch cows partake of the fodder freely, either green or dry. Where the peas were ploughed under, oats were sown the following spring. The oats withstood the effects of the blight better than oats on an adjoining field, that had been planted to corn and heavily manured the previous year. A good stocking of timothy, red top, and clover was also obtained with the oats.

S. W. Hayes, of Granby, grew the crop for green manuring in 1889. The following extract is taken from his report:

> The soil was a light, sandy loam, and the subsoil sandy. One bushel of seed was sown to the acre, broadcast, and the crop reached a height of eighteen inches, the ground being well stocked. The crop was ploughed under the last part of September and the field sown to rye. The effect was good, the rye having nice full heads. It was one-third heavier than where no peas were grown the previous year. On some land beside this a standard commercial fertilizer was used at the rate of 500 lbs. per acre. The rye was about the same as where cow peas were used, but the peas leave the land in better condition.

Although no extensive nor very accurate tests have been undertaken, it will be observed that results of considerable interest have been obtained. The plant makes a valuable protein fodder. When fed to stock it will restore to the land large quantities of nitrogen through the manure. The plant is able to obtain nitrogen from natural sources, much of it probably coming from the air. Its value as a fodder has been well established. While no accurate experiment in this line has been made in this State, we believe it may prove one of the best crops for green manuring. Its value for use in improving light "plain land" soils is especially worthy of the consideration of farmers.

SPECIAL NITROGEN EXPERIMENT ON GRASS

BY

C. S. PHELPS AND CHAS. D. WOODS.

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The hay crop of Connecticut is one of the most important and profitable in the list of general farm crops. According to the census of 1880, the area in mowing lands was a little less than ten times the area in corn. The introduction of improved machinery, and the increased use of commercial fertilizers, have aided greatly in lessening the cost of production, and experimental inquiry in feeding has shown the importance of hay and many coarser products.

Grass is apt to respond readily to the application of commercial fertilizers. Slow acting fertilizers, as ground bone or fish scrap, may be applied in the fall, but the more soluble forms can be applied in the spring. The roots of grass are well distributed through the soil, and are active from early spring until late autumn, while the roots of most hoed crops are not well developed until summer, and early cease to gather plant food. The soluble forms of plant food, especially nitrogen compounds, are more or less readily leached by rain waters below and beyond the reach of the roots of many plants. Grasses catch and utilize the fertilizing materials which would escape the roots of hoed crops.

Even where barnyard manures are applied as "top dressing" during the fall or winter, a light application of nitrate of soda or sulphate of ammonia in the spring, is often profitable. The crop is greatly benefited in its early growth by the readily available nitrogen which these supply, while the slower acting yard manures become available later in the season.

PURPOSE OF THE EXPERIMENT.

The experiment herewith reported upon was undertaken for the purpose of studying the effects of nitrogenous fertilizers upon grass, as shown by:

1. The yield of grass and hay per acre.
2. The financial results.
3. Chemical composition and feeding value of the crop.

DETAILS OF THE EXPERIMENT.

The experiment was similar to the "Special Nitrogen" experiments with corn, described in the previous annual Reports,* and in another part of this Report. It will be observed that plots 1 to 5, on which nitrogen, phosphoric acid, and potash are applied singly, and two by two, and also plot 6, with mixed minerals, were omitted. These plots were left out of the experiment for lack of room in the field, and not because interesting results might not be expected from them. It was with a good deal of reluctance that plot 6, with mixed minerals, was omitted, as it is very desirable in the special nitrogen experiments that a mixed mineral plot be on either side of the nitrogen groups. The general plan of the experiment was to apply the same quantities of mineral fertilizers (potash and phosphoric acid) to all the plots, and to add nitrogen to all except two, at the rate of 25, 50 and 75 lbs. per acre. It was intended that nitrogen in the three forms, nitrates, ammonia salts, and organic nitrogen, should enter into the test. The results from the first two forms are reported herewith, and are worthy of thoughtful consideration.

The field has a gentle slope to the south and the southwest, but not enough to occasion the washing of fertilizers from one plot to another. The plots, which contained one-eighth of an acre, were laid out so as to conform as nearly as practicable to the slope of the field, running up and down. They are 302.5 feet long by 18 feet wide, with unfertilized strips 3 feet wide between each plot.

The land of the plots reported upon has been in grass for several years, without the application of fertilizers of any kind. The parts of the field covered by the plots to which nitrogen as organic nitrogen (dried blood) was applied, had a light application of compost in the fall of 1888, and as this appeared to affect the crop considerably this year, these plots are not included in the report.

A mixed variety of grasses grew on the field in 1889, consisting chiefly of timothy, red top and Kentucky blue grass, with a slight admixture of clover.

The soil is a medium heavy loam, and the subsoil is slightly clayey and adhesive. The soil was in a low state of fertility, as is shown by the small yield on the unmanured plots the present season. The land is not quickly affected by drought, and appears to retain fertilizers readily. The natural drainage is good.

The plan of the experimental field is shown on the next page:

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* See Reports of the Station, 1888, pp. 72 to 89; 1889, pp. 103 to 119.

SPECIAL NITROGEN EXPERIMENT ON GRASS.

PLAN OF EXPERIMENTAL FIELD.

Each plot one-eighth acre. Unmanured strips separate the plots. The weight of fertilizers and of nitrogen are given in *pounds per acre.*

PLOT 0.	Nothing.	
PLOT 7.	Mixed Minerals, as 6 a, 480 lbs. Nitrate of Soda, - 160 lbs.	Nitrogen, - 25 lbs.
PLOT 8.	Mixed Minerals, as 6 a, 480 lbs. Nitrate of Soda, - 320 lbs.	Nitrogen, - 50 lbs.
PLOT 9.	Mixed Minerals, as 6 a, 480 lbs. Nitrate of Soda, - 480 lbs.	Nitrogen, - 75 lbs.
PLOT 6*a*.	Dissolved Bone-black, 320 lbs. Muriate of Potash, - 160 lbs.	"Mixed Minerals."
PLOT 10.	Mixed Minerals, as 6 a, 480 lbs. Sulphate of Ammonia, 120 lbs.	Nitrogen, - 25 lbs.
PLOT 11.	Mixed Minerals, as 6 a, 480 lbs. Sulphate of Ammonia, 240 lbs.	Nitrogen, - 50 lbs.
PLOT 12.	Mixed Minerals, as 6 a, 480 lbs. Sulphate of Ammonia, 360 lbs.	Nitrogen, - 75 lbs.
PLOT 00.	Nothing.	
PLOT 6*b*.	Mixed Minerals, as 6 a, 480 lbs.	Phosp'c Acid, 54 lbs. Potash, - 82 lbs.

NOTES DURING GROWTH.

The fertilizers were applied April 29th. On May 1st, there was a rainfall of .15 inches, and from the 4th to the 6th of May, the rainfall amounted to 1.8 inches. This heavy fall of rain did not produce any apparent surface flow on the field.

Notes taken one week from the date of application show that there was considerable response to the fertilizers on all of the plots supplied with nitrogen, while the plots having mixed minerals alone showed very little advance over the unmanured plots. In fact, the mineral plots gained but little over the unmanured plots until two or three weeks after the fertilizers were applied.

On June 10th, it was noted that the best growth was upon the plots which had received the most nitrogen, and that very little difference in appearance could be observed between the plots which had nitrate of soda and those which had an equal amount of nitrogen, as sulphate of ammonia. At this date, the blue grass was in full bloom, while the timothy heads were only one-fourth to one-third grown. The crop on the mixed mineral plots appeared to be about one-third heavier than that upon the nothing plots, and the proportion of clover was much greater than appeared on the plots to which nitrogen had been applied.

At the time of cutting, June 25th, the principal grasses were timothy and red top. The timothy was beginning to blossom. The heads of the red top were about three-fourths grown. The blue grass was not as noticeable as it had been earlier, and had pretty generally seeded, and on the unmanured plots was dry and woody. Red and white clover was a little past full bloom. There was a large proportion of clover, especially of white clover, on the mixed mineral plots. The proportion of clover was greater on the plots of the sulphate group (10, 11, and 12) than it was on those of the nitrate group (7, 8, and 9). The grass on the plot directly entering into the experiments was cut June 25th. A Eureka machine (center cut) was used, and the grass on the unfertilized strips between the plots was left standing until the crop on the plots was harvested. The hay was weighed and put in the barn the afternoon of the 26th.

RESULTS OF THE EXPERIMENT.

YIELD PER ACRE.

In Table 8, which follows, comparative yields per acre are shown. The field weights for each plot are calculated to a uniform water basis of 11 per cent. moisture (89 per cent. dry matter).

The yields obtained on the plots having no manure (0, and 00) and those having minerals alone (6*a* and 6*b*), would seem to indicate that the soil is tolerably uniform. Plot 0 is on a steeper incline than the others, and it may be that it has lost more than the others by washing in previous years.

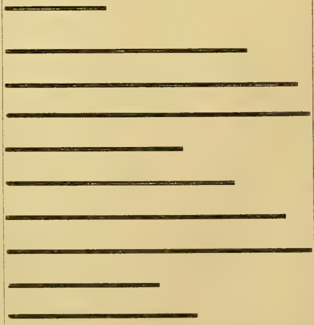
The notes taken during the growing season show that the proportion of clover, especially white clover, was considerably increased on the mineral plots. Hence part of the increase in yield on the mixed mineral plots above those to which no manure was applied, was due to clover. The inference, therefore, is that the grasses did not respond in a marked degree to mineral fertilizers. These results are in accord with the common observation, that mineral fertilizers, and particularly potash, favor the growth of clover. The presence of available nitrogen seems to have been necessary to produce any marked increase in yield of the ordinary grasses.

The yield on the plots supplied with nitrogen appears to have been dependent upon the quantity of nitrogen supplied rather than the form in which it was applied. The yield was practically the same on all the plots supplied with like amounts of nitrogen, whether from nitrate of soda or sulphate of ammonia. This favors the assumption that the soil was reasonably uniform and that the grasses responded directly to the nitrogen. As is readily seen from the table (8), the yield with 75 lbs. of nitrogen was very little more than with 50 lbs. per acre:

Table 8.

SPECIAL NITROGEN EXPERIMENT ON GRASS.

Yield of Hay per Acre.



No. of Plot.	FERTILIZERS.		YIELD PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Lbs.
0	Nothing,	—		1920
7	Mixed Minerals, Nitrate of Soda,	480 100		4759
8	Mixed Minerals, Nitrate of Soda,	480 320		5874
9	Mixed Minerals, Nitrate of Soda,	480 480		6032
6*a*	Dis. bone-blk. Mxd Mur. of Pot'sh Min.	320 160		3353
10	Mixed Minerals, Sulp. of Ammonia,	480 120		4672
11	Mixed Minerals, Sulp. of Ammonia,	480 240		5716
12	Mixed Minerals, Sulp. of Ammonia,	480 360		6056
00	Nothing,	—		2819
6*b*	Mixed Minerals,	480		3604

FINANCIAL RESULTS.

Table 9, below, shows the cost of the fertilizers, the value of the increase, and the gain or loss per acre.

The cost of the fertilizers in each case, is taken at retail rates, in ton lots, for the ingredients, dissolved bone-black, potash salts, etc. Two dollars per ton are added to cover the cost of mixing, freight, etc. The hay is valued at $12 per ton. While the profits, as estimated from these figures, are not large, there is a fair return in all cases where nitrogen entered into the mixtures. The mixed minerals, by themselves, were applied at a loss.

TABLE 9.

SPECIAL NITROGEN EXPERIMENT ON GRASS.

Weight and Cost of Fertilizers per Acre, Increase of Crop over that of the Nothing Plots, Value of the Increase, and Gain or Loss (–) per Acre.

No. of Plot.	FERTILIZERS.	Weight of Fertilizers.	Cost of Fertilizers.	Total Crop (11 % Water.)	Increase over Nothing Plots.	Value of Increase.	Net Profit or Loss (–).
		Lbs.	$	Lbs.	Lbs.	$	$
0	Nothing, - - - - - -	—	—	1920	—	—	—
7	Mixed Minerals, as No. 6, - - Nitrate of Soda, 25 lbs. Nitrogen,	480 160	12.00	4759	2389	14.33	2.37
8	Mixed Minerals, as No. 6, - - Nitrate of Soda, 50 lbs. Nitrogen,	480 320	15.96	5874	3504	21.02	5.10
9	Mixed Minerals, as No. 6, - - Nitrate of Soda. 75 lbs. Nitrogen,	480 480	19.92	6032	3662	21.97	2.09
6*a*	Dissol'd Bone-black, Mixed Muriate of Potash, Minerals,	320 160	8.00	3353	983	5.90	-2.10
10	Mixed Minerals, as No. 6, - - Sulp. of Am., 25 lbs. Nitrogen, -	480 120	12.44	4672	2302	13.81	1.37
11	Mixed Minerals, as No. 6, - - Sulp. of Am., 50 lbs. Nitrogen, -	480 240	16.88	5716	3346	20.08	3.20
12	Mixed Minerals, as No. 6, - - Sulp. of Am., 75 lbs. Nitrogen, -	480 360	21.32	6056	3686	22.12	.80
00	Nothing, - - - - - -	—	—	2819	—	—	—
6*b*	Mixed Minerals, as No. 6, - -	480	8.00	3604	1234	7.40	-.60

The yields from the nitrate of soda plots (see table 9, above,) were about the same as those obtained from the sulphate of ammonia plots. The cost of the nitrogen, however, in the latter was two cents per pound more than in the nitrate, so that the financial returns are in favor of the nitrate of soda. The most favorable result, a gain of $5, by these figures, was with 320 lbs. of nitrate of soda per acre. Whatever loss may have occurred from the use of potash salt or the dissolved bone-black, or both, diminishes the gain from the use of the nitrogenous fertilizers.

It is sometimes urged that there is much danger of loss of nitrate of soda through leaching, if it is applied in excess of 150 or 200 lbs. per acre. In this experiment, on this field, the past season, the best returns were obtained from the use of 320 lbs. of nitrate of soda. How generally such results would follow, it is impossible to say.

CHEMICAL COMPOSITION OF CROP.

Immediately preceding the field weighings of the crop, three samples were taken for analysis, representing as nearly as practicable the hay of the entire plot. These samples were prepared for analysis in the usual way, and the analyses were made by the methods adopted in August, 1890, by the Association of Official Agricultural Chemists. The results given in the tables, which follow, are, for each plot, the averages of the analyses of the three samples.

Table 10, which follows, contains the percentages of water and water-free substance (dry matter), at time of harvesting, the field weights and the weights of dry matter per acre, and the yield of hay containing 11 per cent. of water.

From this table it will be seen that there is an extreme difference of more than 8 per cent. of dry matter in the hay from the different plots. That is, the hay as cured in the field varied from 70.9 to 79.3 per cent. of dry matter. The afternoon in which the crop was harvested was quite windy and very warm. Plots 10, 11, 12, and 6*b* had from two to three hours more drying than the other plots. If this explains the difference in dryness, and it is difficult to find any other explanation, two hours more drying in the cases of these plots seems to have reduced the water 5 to 8 per cent. below that contained in the hay from the plots harvested earlier in the afternoon.

It will be noticed from the field weights that plot 9, with nitrate of soda, appears to give a much larger yield (7,344 lbs.) than plot 12 (6,904 lbs.) with the same amount of nitrogen in the form of sulphate of ammonia, but when calculated to water-free substance, the results are nearly identical, being 5,357 lbs. in the case of plot 9, and 5,383 lbs. in the case of plot 12. The notes taken during the growing season indicated that these two plots were very nearly alike in respect to kinds and amounts of grasses, and we were at a loss to understand the field weights until the moisture determinations were made. The field weights of the hay from plots 7 and 10, each with 25 lbs. of nitrogen, differ by 650 lbs., but the difference in dry matter on the two plots was only 77 lbs. The same is essentially true of plots 8 and 11, with 50 lbs. of nitrogen. In the case of the plots supplied with mixed minerals, *6a* and *6b*, the field weights are practically identical, differing by only 16 lbs., but the weights of dry matter from the two plots differ by 215 lbs.

These cases serve to illustrate the false deductions that may be drawn from field weighings, without the additional knowledge of the water content of the crop.

TABLE 10.

SPECIAL NITROGEN EXPERIMENT ON GRASS.

Harvest Weights per Acre, Percentages of Water and Water-free Substance, and Pounds of Dry Matter per Acre.

No. of Plot.	FERTILIZERS.	Water.	Water-free Substance.	Field Weights.	Water-free Weights.	Weights with 11 % Water.
		%	%	Lbs.	Lbs.	Lbs.
0	Nothing, - - - - - - - -	21.9	78.1	2184	1707	1920
7	Mixed Minerals, as No. 6, - - Nitrate of Soda, 25 pounds Nitrogen,	26.9	73.1	5784	4230	4759
8	Mixed Minerals, as No. 6, - - Nitrate of Soda, 50 pounds Nitrogen,	29.1	70.9	7360	5221	5874
9	Mixed Minerals, as No. 6, - - Nitrate of Soda, 75 pounds Nitrogen,	27.0	73.0	7344	5357	6032
6a	Dissolved Bone-black, Mixed Muriate of Potash, Minerals -	25.7	74.3	4024	2989	3353
10	Mixed Minerals, as No. 6, - - Sulphate of Ammonia, 25 pounds Nit'gen,	23.7	76.3	5440	4153	4672
11	Mixed Minerals, as No. 6, - - Sulphate of Ammonia, 50 pounds Nit'gen,	23.8	76.2	6672	5081	5716
12	Mixed Minerals, as No. 6, - - Sulphate of Ammonia, 75 pounds Nit'gen,	22.0	78.0	6904	5383	6056
00	Nothing, - - - - - - - -	24.3	75.7	3312	2505	2819
6b	Dissolved Bone-black, Mixed Muriate of Potash, Minerals - -	20.7	79.3	4040	3204	3604

According to the averages given in the composition of American feeding stuffs, compiled by Dr. Jenkins,* hay usually contains from 9 to 12 per cent. of water. In this experiment we have assumed a moisture content of 11 per cent. in the cured hay. The differences between the field weights and the weights calculated to a water basis of 11 per cent. (see Table 10, above), gives the shrinkage that would have occurred if this hay had become as dry as the above average. Taking an average of all the plots, there would have been a shrinkage of about 300 lbs. to the ton. The amount of shrinkage depends, of course, upon the degree of maturity when the hay is cut, and its dryness when put into the barn.

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* Report Conn. Station, 1888, pp. 90 and 91.

Table 11, which follows, gives the proximate composition of the hay from the different plots. The figures, as given, represent in each case the average of the analyses of the three samples taken from each plot. It will be noticed that the composition of the hay from the two unfertilized plots was practically the same, and that this is also true of the crop from the two plots supplied with mixed minerals.

Since clover is much richer in protein than are the grasses, the large increase (nearly 1 per cent.) in percentages of protein in the produce from the mixed mineral plots over that from the nothing plots is doubtless due to the increase in relative amount of clover noted above. The percentages of protein in the hay from the mixed mineral plots, and from those supplied with 25 and 50 pounds of nitrogen, are nearly alike. The relative amount of clover was much less in the hay from the plots supplied with nitrogen than it was in that from the mixed mineral plots. Supposing the composition of the grasses to remain the same, the smaller proportion of clover in the crop from the nitrogen plots would be expected to reduce the percentages of protein. As the percentages of protein are not materially reduced in any case, and in the case of hay from plots 9 and 12, are increased nearly 1 per cent., it would seem to indicate that the addition of nitrogen in the fertilizers increased the percentages of nitrogen in the grasses.

This increase in percentages of protein in the produce from the plots supplied with nitrogen, is in accord with our observations upon maize. So far as these crops are concerned, nitrogenous fertilizers seem to increase the percentages of nitrogen in the crops and thus render them of greater feeding value.

In general, the proportion of fat in the crop did not appear to be affected by the fertilizers used. The percentages vary through a rather narrow range, but not in any definite relation to the amount of nitrogen in the fertilizers. The mineral fertilizers appear to increase the amount of ash in the crop. In the other cases the percentages of ash were but little changed. The percentage of fiber was the highest in the hay from the plots to which nitrogen was applied. The percentage of nitrogen-free extract decreased with the application of nitrogen.

TABLE II.

SPECIAL NITROGEN EXPERIMENT ON GRASS.

Proximate Composition of Hay. — Average Results of Analyses, Calculated on Water-free Substance.

No. of Plot.	FERTILIZERS.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.
		%	%	%	%	%
0	Nothing, - - - - - - - -	7.31	3.63	52.86	31.23	4.97
7	Mixed Minerals, as No. 6, Nitrate of Soda, 25 pounds Nitrogen,	8.37	3.71	48.83	33.54	5.55
8	Mixed Minerals, as No. 6, Nitrate of Soda, 50 pounds Nitrogen,	8.09	3.49	48.69	34.61	5.12
9	Mixed Minerals, as No. 6, Nitrate of Soda, 75 pounds Nitrogen,	9.19	3.51	47.59	34.55	5.16
6*a*	Dissolved Bone-black, Mixed Muriate of Potash, Minerals - -	8.23	3.21	49.96	32.78	5.82
10	Mixed Minerals, as No. 6, Sulphate of Ammonia, 25 pounds Nit'gen,	7.55	3.51	49.39	34.20	5.35
11	Mixed Minerals, as No. 6, Sulphate of Ammonia, 50 pounds Nit'gen,	8.36	4.35	48.11	33.98	5.20
12	Mixed Minerals, as No. 6, Sulphate of Ammonia. 75 pounds Nit'gen,	9.17	3.66	48.39	33.68	5.10
00	Nothing, - - - - - - - -	7.39	3.88	52.34	31.32	5.07
6*b*	Dissolved Bone-black, Mixed Muriate of Potash, Minerals - -	8.23	3.59	50.25	32.09	5.84

PROXIMATE INGREDIENTS PER ACRE.

Table 12 gives the yield of dry matter, and its proximate constituents per acre. The increase in protein on the plots supplied with nitrogen in addition to the mineral fertilizers, is noticeable, and especially so in the case of the plots supplied with 75 lbs. of nitrogen. That the amount of protein per acre increased faster than the dry matter, was to be expected from the results of the chemical analyses given in the preceding table.

The addition of 25 lbs. of nitrogen in the fertilizer should have increased the amount of protein per acre 163 lbs., if the grasses had utilized and converted all of the nitrogen into protein. The largest increase in protein that resulted from the addition of 25 lbs. of nitrogen, was 100 lbs., the smallest, 70 lbs. This would seem to imply that in the most favorable of the results of this experiment there was a loss of part of the nitrogen applied in the fertilizers. The largest increase in the nitrogen of the crop, from the addition of 25 lbs. of nitrogen in the fertilizer, was 16 lbs., and the smallest 11 lbs. In the one case 63 per cent. and in the other 44 per cent. of the 25 lbs. of nitrogen added, were found in the crop.

TABLE 12.

SPECIAL NITROGEN EXPERIMENT ON GRASS.

Water-free Substance and Proximate Ingredients per Acre.

No. of Plot.	FERTILIZERS.	Water-free at Harvest.	Protein.	Crude Fat.	Nitrogen-Free extract.	Fiber.	Ash.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0	Nothing, - - - - - - -	1707	125	62	902	533	85
7	Mixed Minerals, as No. 6, - - Nitrate of Soda, 25 lbs. Nitrogen,	4230	354	157	2065	1419	235
8	Mixed Minerals, as No. 6, - - Nitrate of Soda, 50 lbs. Nitrogen,	5221	423	182	2542	1807	267
9	Mixed Minerals, as No. 6, - - Nitrate of Soda, 75 lbs. Nitrogen,	5357	492	188	2550	1850	277
6*a*	Dissolved Bone-black, Mixed Muriate of Potash, Minerals,	2989	246	96	1493	980	174
10	Mixed Minerals, as No. 6, - - Sulphate of Ammonia, 25 lbs. Nitrogen,	4153	314	146	2051	1420	222
11	Mixed Minerals, as No. 6, - - Sulphate of Ammonia, 50 lbs. Nitrogen,	5081	425	222	2444	1726	264
12	Mixed Minerals, as No. 6, - - Sulphate of Ammonia, 75 lbs. Nitrogen,	5383	494	197	2605	1813	274
00	Nothing, - - - - - - -	2505	185	97	1311	785	127
6*b*	Dissolved Bone-black, Mixed Muriate of Potash, Minerals,	3204	264	115	1610	1028	187

SUMMARY.

THE EXPERIMENT.

The object of this experiment was to observe the effects of nitrogenous fertilizers upon grass as shown by the yield per acre; the financial results; and the chemical composition of the hay. The experiment was similar to the special nitrogen experiments upon corn that have been conducted by the Station in previous years. The plots contained one-eighth acre each, and were separated from each other by unfertilized strips. The field had been in grass for several years and the soil was considerably reduced in fertility. Mineral fertilizers (phosphoric acid and potash) were applied to all the plots except two, which were left unmanured. To the manured plots, except two, nitrogen, in the form of nitrate of soda or sulphate of ammonia, was applied at the rate of 25, 50, and 75 pounds per acre.

THE RESULTS.

The addition of mineral fertilizers increased the yield of clover, especially white clover, but did not seem to increase in any marked degree the yield of grasses.

The yield of hay increased with the quantity of nitrogen supplied, whether it was applied in the form of nitrate of soda or sulphate of ammonia. This favors the assumption that the grasses responded directly to the nitrogen.

The mineral fertilizers, when used alone, were used at a financial loss.

The yields obtained from the nitrate of soda plots were about the same in amount as those from the plots to which corresponding amounts of sulphate of ammonia were applied. In the latter the nitrogen cost two cents per pound more than in the former, so that the financial returns are in favor of the nitrate of soda.

The best financial returns, a gain of $5 per acre, were obtained from the use per acre of 320 pounds of nitrate of soda, (50 pounds of nitrogen), in addition to the mixed minerals.

There was a difference of eight per cent. in the water in the field cured hay. This produced corresponding differences between the field weights and weights of dry matter on the different plots, and emphasizes the fact that conclusions far from true may be drawn from field weighings without the additional knowledge of the water content of the crop.

The application of nitrogenous fertilizers increased the percentages of protein (nitrogen multiplied by 6.25) in the grasses, and somewhat in proportion to the amounts applied. This is in accord with observations made by the Station upon the relation of the protein in maize, corn and stover, to the nitrogen applied in the fertilizers. Since protein, which makes blood, bone, muscle, and milk, is a most important ingredient of food, and is apt to be deficient in our feeding stuffs, this increase of protein from the use of nitrogen is an important matter.

The increase in the amount of nitrogen in the crop did not equal the increased amount of nitrogen supplied in the fertilizers, implying that the plants were not able to avail themselves of all the nitrogen supplied.

PRACTICAL CONCLUSIONS.

Grasses differ from many other crops in the readiness with which they respond to nitrogenous fertilizers. While clover and the other legumes may be called "nitrogen gatherers," the grasses, such as timothy, red top, etc., must be classed with the "nitrogen consumers." Fertilizers containing potash or phosphoric acid without available nitrogen, are usually much less effective for grass than if they have nitrogen in addition. It would seem desirable that fertilizers for grass lands should, therefore, contain considerable quantities of nitrogen in a readily available form. Their use has the two-fold advantage of increasing the total yield and the feeding value of the crop. The extent to which hay is used as a fodder indicates an important place for commercial fertilizers in its production.

CO-OPERATIVE FIELD EXPERIMENTS WITH FERTILIZERS.

BY

C. S. PHELPS.

The Station has continued its coöperative field experiments through a third year, the plan being essentially the same as that adopted in the spring of 1888.

These experiments are, perhaps, of greater value to the farmer who conducts them than to any one else; not only does he gain a knowledge of particular soils, but at the same time he is led to appreciate the great need and importance of scientific work. Through discussions in Granges and Farmers' Clubs he also succeeds in interesting many others. The value of the tests and their application will become more general, as they are continued over a period of years.

The experiments have been of three classes: "Soil Tests," "Special Nitrogen Experiments," and a third class designated as "Special Corn Experiments." The last were planned for the purpose of studying the most profitable mixtures for use on farms where the soil test had already indicated some of the peculiarities of the soil.

The object of the experiments may be stated briefly as follows:

1. To work directly upon farm lands in different parts of the State, and to aid the owners in learning the deficiencies of their soils and the requirements of their crops.

2. To help farmers in becoming familiar with the forms and action of fertilizing materials containing phosphoric acid, potash, and nitrogen, and to better understand their profitable use.

3. To encourage a spirit of investigation; and thus to gradually develop a number of farm experimenters, whose work will be useful not only to themselves, but in a larger degeee to their communities and to the agriculture of the State.

The degree of interest manifested in the work by farmers in general is very encouraging, and the care and accuracy exercised by those to whom the work has been entrusted is all that could be expected.

The general plan and scope of the work is discussed only briefly in this report, the following pages being occupied mainly with a discussion of the results obtained during the year 1890. Directions for the experiments will be found in Bulletin 1 and its supplement, and in the Second Annual Report of the Station.* The reader is referred to these for a detailed plan of the work, and for information that would aid in carrying out the experiments.

Besides the work done at the Station, the following persons have coöperated in this line of experimenting, during the past year:

	POST OFFICE.
M. H. Dean, - - - - -	Falls Village.
R. S. Hinman, - - - - -	Stevenson.
K. B. Loomis, - - - - -	South Manchester.
Clifton Peck, - - - - -	Lebanon.
J. H. Tucker, - - - - -	Lebanon.
G. A. Ross, - - - - -	Jewett City.
Frank Day, - - - - -	Danielsonville.
L. H. Healey, - - - - -	North Woodstock.
C. E. May, - - - - -	East Woodstock.

The more important details of the experiments, as the laying out of the plots, application of the fertilizers, weighing and harvesting crop, etc., have been done, wherever practicable, under the direct supervision of the Agriculturist or his assistant, and samples for complete chemical analyses were, in all cases, taken either by the Agriculturist or the Assistant Chemist.

In a number of cases the experiments have been continued through two or three years on the same field, and results of added interest have thus been obtained. Deductions from a single experiment are often misleading and unreliable. If the soil is naturally quite well supplied with plant-food, or if a sod is ploughed under, the first year's crop will oftentimes show but little increase on any plot, as a result of the fertilizer. Differences due to the season are large and often greater than those due to the soil or fertilizers. Variations caused by irregularities in the soil can also be better understood and overcome by extending the work through a series of years. For these reasons we favor and recommend a repetition of the work whenever practicable.

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* Pages 91–106.

In connection with nearly all of these experiments, rainfall records have been kept during the growing season. These, as a rule, have been made in close proximity to the experimental fields. The importance of records near at hand is shown by the differences in rainfall between places but a few miles apart. In another part of the Report will be found the meteorological summary, and the rainfall for the growing season.

The fertilizing materials were in all cases supplied by the Station, in standard commercial forms, such as nitrate of soda, dissolved bone-black, sulphate of ammonia, dried blood, and muriate of potash. These were mixed under the supervision of the Assistant Agriculturist, a short time before being needed for use. In all of the experiments here described, the cost of the fertilizer is estimated from the retail selling prices of the materials, plus $2.00 per ton for mixing and freights.

MOISTURE TESTS OF CORN.

Pounds Required for a Bushel of Dry Shelled Corn.

The percentages of water in the crop from different fields is found to vary widely. The field weights are not an exact measure of the valuable substance of the crop. It would be very incorrect to assume, in all cases, that a given weight of ears at harvest would produce a bushel of dry corn. The moisture, and the proportion of cob varies greatly in different varieties. The time of harvest has a marked effect on the amount of water in the crop.

From most of the experiments large samples, representing about an average of the crop, were taken for moisture determinations. Samples of the hard ears (good) and of the soft ears and nubbins (poor) were taken separately. These were partially dried in a warm room, and after the samples had reached about a constant weight, were re-weighed, shelled, and the proportion of corn and cob obtained. Two quart samples of the grain were then sealed in jars, and taken at once to the laboratory for complete moisture determinations.

With the water-free substance (dry matter) known, the corn could be easily calculated to a uniform water basis. The average amount of water in commercial flint corn is found to be about 11 per cent.* In giving the yields per acre all of the results are reported on this basis.

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* Annual Report of the Connecticut Agricultural Experiment Station, 1888.

Table 13.

Percentages of Dry Matter of Corn in Ears (Grain and Cob), and the Number of Pounds of Ears Required for a Bushel of Shelled Corn.

Name and Locality.	Water-free Corn in Sample.	Partially Dry Corn, in Sample, (11 % Water.)	Pounds of Ears at Harvest to Equal 56 lbs. Shelled Corn, with 11 % Water.
	%	%	%
R. S. Hinman, Oxford, (Good)	57.84	65.1	86.0
R. S. Hinman, Oxford, (Poor)	52.53	59.1	95.0
J. H. Tucker, Lebanon, (Good)	59.91	67.4	83.0
J. H. Tucker, Lebanon, (Poor)	56.66	63.7	88.0
Clifton Peck, Franklin, (Good)	59.33	66.7	84.0
Clifton Peck, Franklin, (Poor)	42.53	47.8	117.0
L. H. Healey, N. Woodstock (Good)	61.00	68.6	82.0
L. H. Healey, N. Woodstock (Poor)	54.60	61.4	91.0
K. B. Loomis, S. Manchester (Good)	53.13	59.8	94.0
K. B. Loomis, S. Manchester (Poor)	40.41	45.5	123.0
G. A. Ross, Jewett City, (Good)	62.00	70.1	80.0
G. A. Ross, Jewett City, (Poor)	58.80	66.2	85.0
Frank Day, Danielsonville, (Good)	62.30	70.0	80.0
Frank Day, Danielsonville, (Poor)	53.80	60.6	92.0
C. E. May, E. Woodstock, { Good Poor }	62.75	70.6	79.3

From the above table, it will be seen that the percentages of water-free corn at harvest vary widely in the crop from different fields. These variations are due quite largely to the time of harvest, but more to differences in varieties, which affect the degree of maturity and proportion of corn to cob. Mr. Hinman, Mr. Loomis, and Mr. Healey grew the same variety. The crop grown by Mr. Loomis was harvested October 11th, while the other two fields remained undisturbed for about four weeks longer. From Mr. Healey's field, 82 lbs. of ears gave a bushel of dry shelled corn, and from Mr. Loomis', 94 lbs. were required for a bushel. The fertilizers used were the same in both cases.

The degree of maturity, as affected by differences in varieties, seems to have a greater effect on the moisture than the time of harvest. Mr. May's crop was harvested October 9th, yet the amount of moisture is quite small. The variety was a very early one, so that the crop was cut about September 1st. At harvest the ears were noticed to be hard, and the proportion of soft corn was smaller than in any of the other experiments.

SOIL TEST EXPERIMENTS.

Experiments of this class may be said to have for their object the analysis of the soil by the living plant. Chemical analysis is tedious and costly, and reveals but little with regard to deficiencies of soil or the available amount of plant-food that may be present. The growing plant sends its roots in every direction through the soil. If plant-food is present in an available form, and the moisture, temperature, etc., are favorable, the plant will find it and thrive. If any of the essential ingredients are lacking, the results obtained at harvest will nearly always reveal the deficiency. By this means it is possible to learn whether a soil specially needs phosphoric acid, potash, or nitrogen to produce a given crop.

A knowledge of the soil will aid in ascertaining in what form and combinations these ingredients can best be supplied. In addition to this, however, it is desirable to study the feeding capacities of plants and the chemical composition of the crop. It is only by a study of all these points that we can come to a rational understanding of the use of commercial fertilizers.

It is quite generally appreciated that plants differ widely in their possession of the special power by which they are enabled to gather their food supply from natural sources and to which the term "feeding capacity" has been applied. Plants like clover, vetch or cow pea, are no longer fertilized in accordance with the composition of the crop. The fact that many plants of this class are generally acknowledged to be able to gather much of their nitrogen from the air, has led to the use of mineral fertilizers in their growth. Every farmer can study the peculiarities of his soil and of his crops, and then supply such fertilizers as will meet their needs.

From a study of the results obtained during the past three years, at Oxford, Falls Village, and Lime Rock, it appears that an entirely different kind of fertilizer is needed for corn on the soil of the Housatonic Valley from that needed in most other parts of the State. Further trials in different parts of the Valley may give new light on the subject, but the work done thus far shows that potash fertilizers are most needed in the soils where the tests were made.

SOIL TEST EXPERIMENT.

PLAN OF EXPERIMENTAL FIELD.

Each plot one-tenth acre. Unmanured strips separate the plots. The weight of fertilizers and their valuable ingredients are given in *pounds per acre.*

PLOT O.	Nothing.			
PLOT A.	Nitrate of Soda, -	160 lbs.	Nitrogen, -	25 lbs.
PLOT B.	Dissolved Bone-black,	320 lbs.	Phosphoric Acid,	54 lbs.
PLOT C.	Muriate of Potash, -	160 lbs.	Potash, - -	82 lbs.
PLOT D.	Nitrate of Soda, - Dissolved Bone-black,	160 lbs. 320 lbs.	Nitrogen, - Phosphoric Acid,	25 lbs. 54 lbs.
PLOT E.	Nitrate of Soda, - Muriate of Potash, -	160 lbs. 160 lbs.	Nitrogen, - Potash, - -	25 lbs. 82 lbs.
PLOT F.	Dissolved Bone-black, Muriate of Potash, -	320 lbs. 160 lbs.	Phosphoric Acid, Potash, - -	54 lbs. 82 lbs.
PLOT G.	Nitrate of Soda, - Dissolved Bone-black, Muriate of Potash, -	160 lbs. 320 lbs. 160 lbs.	Nitrogen, - Phosphoric Acid, Potash, - -	25 lbs. 54 lbs. 82 lbs.
PLOT H.	Plaster, - - -	400 lbs.		
PLOT OO.	Nothing.			

PLAN AND RESULTS OF SOIL TEST EXPERIMENTS.

The plan of experiments for soil tests consists in applying on parallel plots of land, fertilizers containing nitrogen, phosphoric acid, and potash, singly, two by two, and all three together. The arrangement of the experiment, the kinds and quantities of the materials used, and the valuable ingredients contained in them, are shown in the plan of the field on the opposite page.

THE EXPERIMENTS.

Experiments of this class have been carried out at Lime Rock, Oxford, Franklin, East Woodstock, and at the Station. On the following pages, the comparative yields are shown by means of diagrams. The fertilizers are given at the left of the diagram. The length of the line represents the comparative yield per acre of shelled corn from the different plots. The figures given in the last column show the number of bushels of shelled corn per acre. At the close of this article will be found a series of tabular statements giving the results in detail. In all cases, the yield of shelled corn per acre is reported on the basis of 11 per cent. water, and the stover on the basis of field weights.

EXPERIMENTS BY M. H. DEAN.

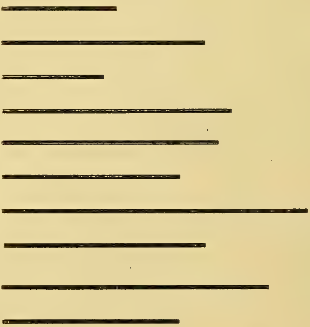
Mr. Dean's experiment has been continued through two years on the same plots. As certain marked peculiarities show themselves each season, it has been thought advisable to reprint the results obtained in 1889. The experiment for 1890 is the same in kind as the one of the year before. It will be noticed, that while the order of plots and the kind of fertilizer remain the same, the amounts per acre are doubled. A new plot, G*a*, was substituted for H. It is similar to G (1890), except that the amount of dissolved bone-black was again doubled, this material being used at the rate of 1,280 lbs. per acre.

The field of this experiment is located in the Housatonic Valley. The soil is a light loam, with very little vegetable matter, and apparently worn down by previous cropping without manure. The yield in all cases was light, due in part to the worn-out condition of the soil and in part to the unfavorable season. Inequalities of soil have modified the results somewhat, but not enough to destroy their value.

An inspection of the diagram for 1889, shows that potash gave the most marked results; that nitrogen increased the yield somewhat, and that phosphoric acid had little or no effect.. The largest yield was on plot E, where both nitrate and potash were used. That the yield on this plot was larger than that on plot G, may have been due to inequalities in the soil.

SOIL TEST WITH FERTILIZERS ON CORN.—1889.

By M. H. DEAN, Lime Rock.

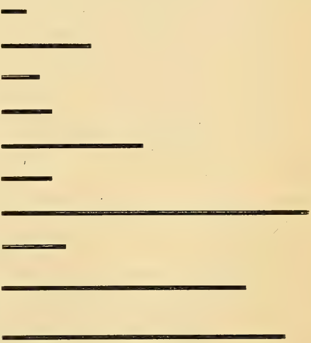
Plot.	FERTILIZERS.		YIELD SHELLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
o.	Nothing, - -	—		9.9
A.	Nitrate of Soda, -	160		16.9
B.	Dis. Bone-black, -	320		9.1
C.	Muriate of Potash,	160		18.8
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320		18.0
oo.	Nothing, - -	—		14.7
E.	Nitrate of Soda, - Muriate of Potash,	160 160		25.3
F.	Dis. Bone-black, - Muriate of Potash,	320 160		17.4
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash,	160 320 160		22.1
H.	Plaster, - -	400		14.8

In the "Soil Test" for 1889, potash was the ingredient having the greatest effect. In 1890, (see diagram on following page), nitrogen produced the most marked results. We copy the following notes from Mr. Dean's report for 1890, showing the appearance of the crop during growth:

> Blight on some of the poorer plots in August, killing many of the leaves. Worst on o and D, and considerable on A, B, and oo. August 25, plots E, G, and G*a* look very fine. F tall and good stalks, but no ears. Plots without nitrogen lighter in color than the others.

SOIL TEST WITH FERTILIZERS ON CORN.—1890.

By M. H. DEAN, Lime Rock.



Plot.	FERTILIZERS.		YIELD SHELLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
O.	Nothing, - -	—		3.9
A.	Nitrate of Soda, -	320		12.9
B.	Dis. Bone-black, -	640		5.0
C.	Muriate of Potash,	320		7.2
D.	Nitrate of Soda, - Dis. Bone-black, -	320 640		17.0
OO.	Nothing, - -	—		7.3
E.	Nitrate of Soda, - Muriate of Potash,	320 320		44.4
F.	Dis. Bone-black, - Muriate of Potash,	640 320		8.8
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash,	320 640 320		35.0
G*a*.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash,	320 1280 320		40.4

From Table No. 14, giving results in detail, it will be noticed that the field weights of stover are essentially the same on plots C and F, as on the plot (E) giving the largest yield, but that there was very little corn on the first named plots. This feature was very noticeable at harvest, many of the stalks on plots without nitrogen showing no indication of ears.

While nitrogen gave the best yield of corn where the ingredients were applied singly, the crop of grain in all cases was light, unless potash was combined with the nitrogen. The results of this experiment show that, in this case, nitrogen played a most important part in the formation of seed, and that potash produced the most marked effect on the growth of stalks.

The most striking results of these experiments are the very small returns from the use of soluble phosphates. Plot E, in 1889, gave a larger yield than plot G, which had the same quantities of nitrogen and potash, but in addition about 50 lbs. of phosphoric acid from dissolved bone-black. It seemed doubtful the first year if this falling off could be ascribed to the poorer condition of the soil on G, as the plots were separated only by a single plot and the soil appeared quite uniform. In the experiment of 1890, with the same relative amounts of the different ingredients, G still gave a smaller yield than E, while G*a*, similar to G, but having double the quantity of phosphoric acid, gave a little increase over G, but not as heavy a crop as E, which had no phosphoric acid.

This apparently injurious effect of soluble phosphate is most frequent on sandy soils, naturally deficient in nitrogen. The most plausible explanation seems to be that the soluble phosphoric acid, in the absence of an abundant supply of available nitrogen, checks the growth and hastens maturity. The leaves turn yellow and the crop prematurely ripens, and a smaller yield results.

EXPERIMENT BY R. S. HINMAN.

Mr. Hinman's field is also located on the Housatonic river. The soil is evidently terrace formation. The experiment has been continued through three years on the same plots, with the same kinds and amounts of fertilizers.

In 1888, the results were not decisive. The crop was evidently supplied from accumulated stores of plant-food in the soil. Much of this, probably, came from the heavy sod ploughed under.

In 1889, the most marked effect came from the use of potash salts.

This year (1890) the results were essentially the same as for 1889. The relative yields from the different plots remain in practically the same order. Potash produced the most marked effect. In every case where it was omitted, there was a heavy falling off in the yields, both of corn and stover. Phosphoric acid, when used alone, seems to have produced a better growth than nitrogen (compare plots A and B). When these two ingredients were combined with potash, however, the nitrogen appears to have a greater influence on the crop (compare E and F).

As in Mr. Dean's experiment, both nitrogen and potash seem to be needed to produce a fair crop. Phosphoric acid seems to be of more importance than in Mr. Dean's experiment, yet the increase from its use was small. Plot G gave four bushels more of shelled corn than E. The amounts of nitrogen and potash were the same on both, but plot G had, in addition, about 50 lbs. of phosphoric acid.

Plot I was supplied with nitrogen from a variety of sources, chiefly from pulverized bone and meat, dried blood, sulphate of ammonia, and nitrate of soda. The yield on this plot, both in 1889 and 1890, was considerably less than where nitrogen in one form (plot G) was used. It may be that the nitrogen in the case of I was not rendered available as fast as needed by the crop.

SOIL TEST WITH FERTILIZERS ON CORN.

By R. S. HINMAN, Oxford.

(P. O., Stevenson.)

Plot.	FERTILIZERS.		YIELD SHELLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
A	Nitrate of Soda, -	160		8.9
B.	Dis. Bone-black, -	320		12.7
C.	Muriate of Potash,	160		19.4
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320		16.9
E.	Nitrate of Soda, - Muriate of Potash,	160 160		34.5
o.	Nothing. - -	—		14.4
F.	Dis. Bone-black, - Muriate of Potash,	320 160		28.7
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash,	160 320 160		39.4
H.	Plaster, - -	400		14.4
I.	Complete Fert'zr, Varied Forms,	600		27.2

EXPERIMENT BY CLIFTON PECK.

Mr. Peck's field was part of a worn-out meadow. The soil is quite moist, a clayey loam, with a medium amount of vegetable matter. The subsoil is a tenacious clay. The soil is uneven, a feature which modifies the value of the experiment to quite an extent. The results from the first nothing (o) plot are discarded. The yield was considerably increased, owing to the fact that a number of years ago a hay-stack stood on this part of the field, and the fodder was scattered over quite an area. Plot A also appeared to be somewhat affected by this material. Notwithstanding the inequalities in the soil, soluble phosphate produced quite a marked effect wherever used. (Compare plots B and D with C and E.) The smaller yields on E, F, and G may be explained by the fact that the soil appeared considerably poorer on that side of the field. The soil on this farm is much the same as that on Mr. Tucker's farm, about three miles to the north. Both experiments indicate a deficiency of phosphoric acid in the soil.

SOIL TEST WITH FERTILIZERS ON CORN.

By CLIFTON PECK, Franklin.

(P. O., Lebanon.)

Plot.	FERTILIZERS.		YIELD SHELLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
O.	Nothing, - -	—		—
A.	Nitrate of Soda, -	160		24.0
B.	Dis. Bone-black, -	320		32.3
C.	Muriate of Potash,	160		23.5
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320		29.3
E.	Nitrate of Soda, - Muriate of Potash,	160 160		20.9
F.	Dis. Bone-black, - Muriate of Potash,	320 160		31.0
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash,	160 320 160		28.3
H.	Plaster, - -	400		18.0
OO.	Nothing, - -	—		14.0

EXPERIMENT BY C. E. MAY.

Mr. May's field was part of an old meadow that had been in grass for several years. The soil is a light loam, with a medium amount of vegetable matter, and is well adapted to the growth of corn. The subsoil is a fine, yellow loam. The heavy yields on the nothing plots were probably due to the large amount of vegetable matter ploughed under as turf.

When the ingredients were applied singly, nitrogen produced the most marked effect, and unless nitrogen entered into the mixtures, the yields were, in all cases, light.

When the field was visited August 9th, it was noticed that the growth on the plots without nitrogen was pale yellow in color, and the stalks and ears much smaller (especially plots B and F) than on adjoining plots having nitrogen. Potash used alone had a more marked effect than phosphoric acid (compare C and B). About equally good results were obtained when each of these ingredients were combined with nitrogen. In this experiment nitrogen was clearly the regulating ingredient.

SOIL TEST WITH FERTILIZERS ON CORN.

By C. E. MAY, East Woodstock.

Plot.	FERTILIZERS.		YIELD SHELLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
o.	Nothing. - -	—		45.8
A.	Nitrate of Soda, -	160		52.0
B.	Dis. Bone-black, -	320		40.4
C.	Muriate of Potash,	160		46.0
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320		55.1
E.	Nitrate of Soda, - Muriate of Potash,	160 160		54.5
F.	Dis. Bone-black, Muriate of Potash,	320 160		43.6
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash,	160 320 160		57.4
H.	Plaster, - -	400		44.8
oo.	Nothing, - -	—		42.6

EXPERIMENT BY THE STATION.

The Station field was used in growing corn for two years before the experiment here reported was begun. No fertilizers of any kind were applied, the object being to reduce the fertility.

The field slopes gently to the south and west, but not enough to cause serious washing. The soil is a heavy loam, and the subsoil is a yellow, compact clay loam. In 1889, it was noticed that the soil seemed to be poorer toward the west side of the field. For this reason the field was laid out into two half-acre experiments, the order of the plots on the two being reversed, as per diagram. All of the plots were laid out running north and south.

ARRANGEMENT OF PLOTS IN STATION EXPERIMENT.

UNMANURED STRIPS SEPARATE THE PLOTS.

For fertilizers used on plots, see diagram on opposite page.

EAST.

	PLOT O.	PLOT Y.	
	PLOT A.	PLOT X.	
	PLOT B.	PLOT OOO.	
	PLOT C.	PLOT G.	
	PLOT OO.	PLOT F.	
NORTH.	PLOT D.	PLOT E.	SOUTH.
	PLOT E.	PLOT D.	
	PLOT F.	PLOT OO.	
	PLOT G.	PLOT C.	
	PLOT OOO.	PLOT B.	
	PLOT X.	PLOT A.	
	PLOT Y.	PLOT O.	

WEST.

Beside the regular soil test, two other plots were added, one (Y) with a medium amount of stable manure and the other (X) with a smaller quantity of manure, but in addition dissolved bone-black at the rate of 320 lbs. per acre. The stable manure was harrowed in just before planting, and the bone-black was applied in the hill.

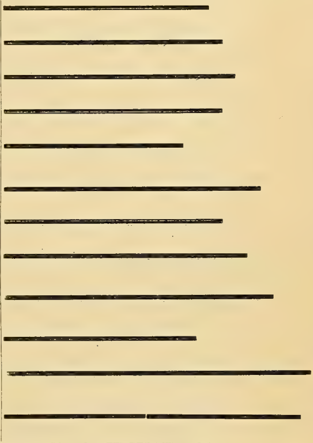
The inequalities in the soil were not entirely overcome and modify the results somewhat. The nothing plots, however, are quite uniform. The growth on plots having phosphoric acid was heavier and darker colored throughout the season. The results show that phosphoric acid had the most marked effect, nitrogen considerable, while potash gave but little increase over nothing. There is no very great increase from the use of any of the ingredients, and it seems probable that the soil was supplied with accumulated stores of fertility, which the two years cropping had not entirely exhausted.

On plot Y a mixture of stable manure was used at the rate of eight tons per acre. Assuming the average composition of rich stable manure, 80 lbs. of nitrogen, 64 lbs. of potash, and 80 lbs. of phosphoric acid were supplied. The cost, estimated at $4 per cord, is a little greater than for plot G, with the complete fertilizer. Plot X had one-fourth less stable manure than Y, but in addition dissolved bone-black at the rate of 320 lbs. per acre. The cost and the yield, in this case, were essentially the same as for Y.

SOIL TEST WITH FERTILIZERS ON CORN.

By the Station, Mansfield.

Plot.	FERTILIZERS.		YIELD SHELLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
O.	Nothing, - -	—		28.9
A.	Nitrate of Soda, -	160		32.4
B.	Dis. Bone-black, -	320		33.3
C.	Muriate of Potash,	160		30.4
OO.	Nothing, - -	—		26.7
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320		36.1
E.	Nitrate of Soda, - Muriate of Potash,	160 160		32.8
F.	Dis. Bone-black, - Muriate of Potash,	320 160		34.4
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash,	160 320 320		37.4
OOO	Nothing, - -	—		28.5
X.	Stable Manure, - Dis. Bone-black, -	12000 320		44.1
Y.	Stable Manure, -	16000		43.6



SPECIAL NITROGEN EXPERIMENTS.

The object of this class of experiments is to study the effect of larger and smaller quantities of nitrogen on different crops, while the amount of mineral fertilizers remains constant. There are two prominent points to be considered: the effect of the fertilizer on the yield, and the effect on the composition and feeding value.

Plants differ widely in the readiness with which they respond to applications of nitrogen, and in their peculiar powers of gathering nitrogen from natural sources. Clover, vetches, alfalfa, and other legumes seem to demand but little nitrogen, while grass, oats, and wheat require a great deal, and generally increase in yield with increased applications of this element.

Most of the commercial forms of nitrogen are readily lost to the plant in many soils. The surface soil fails to hold it, especially on light soils with porous subsoils, and on all soils more or less nitrogen escapes in the drainage. Losses of this kind are greatest in quick acting fertilizers, as nitrate of soda and sulphate of ammonia. Nearly all soils retain the mineral constituents quite completely, very little phosphoric acid or potash being found in drainage waters. The question of how to apply nitrogen rationally and economically becomes one of vast importance to the farmer.

Experiments of this kind have been conducted during the past year on grass, potatoes, and oats. The experiment on grass will be found on pages 44–56 of this Report.

EXPERIMENT ON POTATOES, BY M. H. DEAN.

The field planted to potatoes by Mr. Dean is adjoining the soil test experiment described on page 63. The soil is a light loam, somewhat sandy, with a light loam subsoil, much like the surface soil, except it contains a less amount of vegetable matter. The seed was planted in drills 3.3 feet apart, with five hills to the rod. Three-hundredths of each plot was planted with White Star potatoes and the balance with Beauty of Hebron. It will be noticed that the mixed mineral plots (6*a* and 6*b*) gave a large increase over the nothing plots, but that little benefit seemed to result from the use of nitrogen in any of its forms. The average yield on the nothing plots was at the rate of 137 bushels per acre, while the average of the mixed mineral plots was 218 bushels. The quality of the potatoes was good, and the crop appeared free from blight and rot throughout the season. The reason for the slight gain from the use of nitrogen is difficult to explain. This soil has shown a marked deficiency in potash. It is possible that there was not a sufficient supply of this ingredient to meet the demands of the crop, and as a consequence the plants were unable to utilize the nitrogen supplied. Nitrogen seemed to be the regulating ingredient in the soil test with corn, on the adjoining field. Potatoes usually respond freely to the application of nitrogen, and it is possible that more benefit would have come from the nitrogen, if the minerals had been supplied in different proportions. More potash may have been needed to meet the peficiencies of the soil.

SPECIAL NITROGEN EXPERIMENT ON POTATOES.

By MYRON H. DEAN, Falls Village.

Plot.	FERTILIZERS.		YIELD PER ACRE.	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
0.	Nothing, - - -	—		120
7.	Mxd Min'ls, as No. 6, Nitrate of Soda, -	480 160		232
8.	Mxd Min'ls, as No. 6, Nitrate of Soda, -	480 320		233
9.	Mxd Min'ls, as No. 6, Nitrate of Soda, -	480 480		244
6*a*.	Dis. Bone-black, Muriate of Potash. *	320 160		226
10.	Mxd Min'ls, as No. 6, Sulp. of Ammonia, -	480 120		243
11.	Mxd Min'ls, as No. 6, Sulp. of Ammonia, -	480 240		226
12.	Mxd Min'ls, as No. 6, Sulp. of Ammonia, -	480 360		232
6*b*.	Mxd Min'ls, as No. 6,	480		210
13.	Mxd Min'ls, as No. 6, Dried Blood, - -	480 200		218
14.	Mxd Min'ls, as No. 6, Dried Blood, - -	480 400		218
15.	Mxd Min'ls, as No. 6, Dried Blood, - -	480 600		208
00.	Nothing, - - -	—		155

* Mixed Minerals.

EXPERIMENT ON OATS, BY G. A. ROSS.

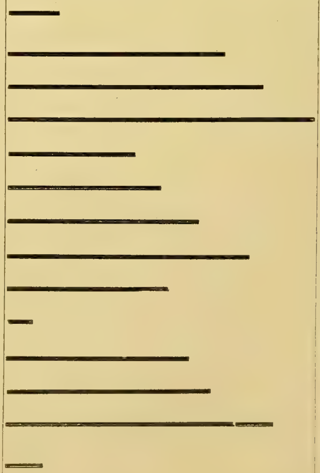
The Station planned a combined experiment on oats and corn for the purpose of studying the relative effect of nitrogen on the two crops. These two plants usually respond very differently to applications of nitrogen. While oats generally give a marked increase in yield from liberal applications of nitrogen, corn does not generally respond freely to this element. The soil of the field used for the experiment was found to be very irregular, as the season advanced. The irregularities appeared to affect the corn more than the oats, and as the stand of corn was poor and irregular on the different plots, that part of the experiment is not published.

The soil is an alluvial formation, a light sandy loam, with a sandy subsoil. The crop appeared to be slightly affected by drought during July. The land was greatly reduced in fertility, as is indicated by the very light yield on the nothing plots. There was quite an increase from the use of mixed minerals, and a still greater increase wherever nitrogen was applied.

Unlike what is generally observed in corn experiments of this class, the oats responded quite markedly to nitrogen. In all of the nitrogen groups, there was a gradual increase in the yields of both grain and straw, as the quantities of nitrogen used were increased. The fertilizers were generally applied at a loss. This, with little doubt, is owing chiefly to "rust" which attacked the crop in June, and to the fact that the season was generally unfavorable for the oat crop.

SPECIAL NITROGEN EXPERIMENT ON OATS.

By G. A. ROSS, Jewett City.

Plot.	FERTILIZERS.		YIELD PER ACRE.	
	Kind.	Lbs. per Acre.	Comparative Scale,	Lbs.
0.	Nothing, - -	—		120
7.	Mixed Minerals, - Nitrate of Soda, -	480 160		512
8.	Mixed Minerals, - Nitrate of Soda, -	480 320		592
9.	Mixed Minerals, - Nitrate of Soda, -	480 480		712
6*a*.	Dis. Bone-bl'ck, * Mur. of Potash,	320 160		292
10.	Mixed Minerals, - Sulp. of Ammonia,	480 120		352
11.	Mixed Minerals, - Sulp. of Ammonia,	480 240		440
12.	Mixed Minerals, - Sulp. of Ammonia,	480 360		536
6*b*.	Dis. Bone-bl'ck, * Mur. of Potash,	320 160		384
00.	Nothing, - -	—		56
13.	Mixed Minerals, - Dried Blood, -	480 200		432
14.	Mixed Minerals, - Dried Blood, -	480 400		464
15.	Mixed Minerals, - Dried Blood, -	480 600		624
000	Nothing, - -	—		102

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* Mixed Minerals.

SPECIAL CORN EXPERIMENTS.

This class of experiments was planned for the purpose of studying the best proportions of phosphoric acid and potash for use in growing corn on soils whose peculiarities had already been studied by means of "soil tests." In addition, the profit or loss from the use of the mixtures was also considered.

The most profitable mixture for use in growing any particular crop is a difficult matter to ascertain. This depends not only on the adaptability of the fertilizer to the soil and crop, but very largely on the business tact of the farmer in purchasing. The returns obtained are also dependent upon the season. If drought or an excess of rainfall occurs, the benefit that might otherwise come from the fertilizers will be greatly lessened.

Experiments of this class have been conducted at South Manchester, Lebanon, North Woodstock, and Danielsonville.

As the object was to study the effect of different quantities of the minerals, the nitrogen was kept constant and was supplied in all cases, except on plot G, as nitrate of soda and dried blood. Previously conducted soil tests showed that the soils where these particular experiments were located were more or less deficient in phosphoric acid. For this reason, the amounts of this ingredient used were varied quite widely.

On several of the plots, Thomas slag, a by-product in the manufacture of steel from phosphatic iron ores, was used as a source of phosphoric acid. It is found in the market as a very fine powder, and contains, on the average, 18 to 20 per cent. of phosphoric acid, 6 to 8 per cent. of which is considered available (*i. e.*, soluble in ammonium citrate). The cost of the phosphoric acid in the slag is 5 cents per pound, while in dissolved bone-black the cost is 7½ cents. In the mixtures used in these experiments, 700 pounds of the slag was used at the same expense as 500 lbs. of dissolved bone-black.

A product known as "pulverized tankage" was used on plot G. It is composed of bone, blood, and meat, freed from most of its fat, and ground to a very fine, flour-like powder. It contains about the same quantity of phosphoric acid as the slag, but in addition 4 to 6 per cent. of nitrogen. Owing to the fineness of this tankage, its phosphoric acid is supposed to be quite largely available the first season.

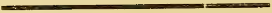
All of the other substances used in these mixtures are standard fertilizing products, and hence no special description of the materials is thought necessary.

EXPERIMENT BY K. B. LOOMIS.

The soil of Mr. Loomis' field is a medium compact loam, with a reddish clay subsoil. In 1889, phosphoric acid brought the greatest increase, while potash increased the product somewhat. This year (1890) the largest yields and the best financial returns were obtained where the soluble phosphate was used (plot H). Where muriate of potash was used at the rate of 150 lbs. per acre, with 500 lbs. of Thomas slag, the yield of corn was considerably increased over plots with less potash. (Compare plots D and E with F.) It seems from this one season's work that the Thomas slag was not as economical as the dissolved bone-black. The best results on this soil appear to come from the use of large quantities of soluble phosphates, together with 100 or 150 lbs. of muriate of potash, and about 25 lbs. of nitrogen from some readily available source.

SPECIAL FERTILIZER EXPERIMENT ON CORN.

By K. B. LOOMIS, So. Manchester.

Plot.	FERTILIZERS.		YIELD SHELLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
O.	Nothing, - - -	—		21.2
A.	Nitrate of Soda, } * High grade Blood, } Muriate of Potash, - Thomas Slag, - -	75 100 100 500		51.3
B.	Nit. Mixture, as A, - Muriate of Potash, - Thomas Slag, - -	175 100 600		50.1
C.	Nit. Mixture, as A, - Muriate of Potash, - Thomas Slag, - -	175 100 700		53.4
D.	Nit. Mixture, as A, - Muriate of Potash, - Thomas Slag, - -	175 50 500		52.0
E.	Nit. Mixture, as A, - Muriate of Potash, - Thomas Slag, - -	175 100 500		54.1
F.	Nit. Mixture, as A, - Muriate of Potash, - Thomas Slag, - -	175 150 500		58.3
G.	Pulverized Tankage, - Muriate of Potash, -	500 100		56.8
H.	Nit. Mixture, as A, - Muriate of Potash, - Dis. Bone-black, - -	175 100 500		61.4
OO.	Nothing, - - -	—		29.9

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* Nitrogen Mixture.

EXPERIMENT BY J. H. TUCKER.

The soil of Mr. Tucker's field is a clay loam, having quite a large amount of organic matter. The subsoil is a tenacious clay. In wet seasons the field is apt to be quite moist. In 1889, this soil responded quite freely to applications of phosphoric acid, but very slightly to potash.

This season (1890) the yields on the nothing plots were quite similar, indicating that the soil is fairly uniform in fertility. In this experiment the best returns came from the use of dissolved bone-black. An amount of Thomas slag costing the same as the bone-black, gave very nearly as large a yield. It will be noticed that the yields increased slightly with the amounts of slag used (compare plots A, B, and C). Large quantities of phosphoric acid and small quantities of potash appear to have given the best financial results on this soil.

SPECIAL FERTILIZER EXPERIMENT ON CORN.

By J. H. TUCKER, Lebanon.

Plot.	FERTILIZERS.		YIELD SHELLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
O.	Nothing, - - -	—		22.9
A.	Nitrate of Soda,	75		37.1
	High Grade Blood, *	100		
	Muriate of Potash, -	100		
	Thomas Slag, - -	500		
B.	Nit. Mixture, as A, -	175		40.0
	Muriate of Potash, -	100		
	Thomas Slag, - -	600		
C.	Nit. Mixture, as A, -	175		43.1
	Muriate of Potash, -	100		
	Thomas Slag, - -	700		
D.	Nit. Mixture, as A, -	175		39.6
	Muriate of Potash, -	50		
	Thomas Slag, - -	500		
E.	Nit. Mixture, as A, -	175		35.3
	Muriate of Potash, -	100		
	Thomas Slag, - -	500		
F.	Nit. Mixture, as A, -	175		36.7
	Muriate of Potash, -	150		
	Thomas Slag, - -	500		
G.	Pulverized Tankage, -	500		37.2
	Muriate of Potash, -	100		
H.	Nit. Mixture, as A, -	175		45.3
	Muriate of Potash, -	100		
	Dis. Bone-black, - -	500		
OO.	Nothing, - - -	—		20.6

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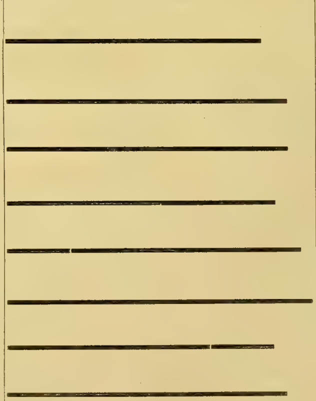
* Nitrogen Mixture.

EXPERIMENT BY L. H. HEALEY.

Mr. Healey's field was on another part of the farm, quite a distance from the field used for the soil test during the past two years. The soil of the two fields appears to be much alike. It is a clay loam, with a compact clay subsoil. A heavy sod was ploughed under in the spring of 1890, and hence the effect of the fertilizers is less marked. The largest yield came from the use of 500 lbs. of slag, with 150 lbs. of potash. In this case, an amount of slag costing the same as 500 lbs. of bone-black, appears to have given better results than the bone-black.

SPECIAL FERTILIZER EXPERIMENT ON CORN.

By L. H. HEALEY, No. Woodstock.



Plot.	FERTILIZERS.		YIELD SHELLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
O.	Nothing, - - -	—		39.6
A.	Nitrate of Soda, *	75		46.5
	High Grade Blood, *	100		
	Muriate of Potash, -	100		
	Thomas Slag, - -	500		
B.	Nit. Mixture, as A, -	175		51.9
	Muriate of Potash, -	100		
	Thomas Slag, - -	600		
C.	Nit. Mixture, as A, -	175		50.5
	Muriate of Potash, -	100		
	Thomas Slag, - -	700		
D.	Nit. Mixture, as A, -	175		49.9
	Muriate of Potash, -	50		
	Thomas Slag, - -	500		
E.	Nit. Mixture, as A, -	175		53.2
	Muriate of Potash, -	100		
	Thomas Slag, - -	500		
F.	Nit. Mixture, as A, -	175		55.0
	Muriate of Potash, -	150		
	Thomas Slag, - -	500		
G.	Pulverized Tankage, -	500		48.2
	Muriate of Potash, -	100		
H.	Nit. Mixture, as A, -	175		49.7
	Muriate of Potash, -	100		
	Dis. Bone-black, - -	500		
OO.	Nothing.	—		

*Nitrogen Mixture.

SPECIAL FERTILIZER EXPERIMENT ON CORN.

By FRANK DAY, Danielsonville.

Plot.	FERTILIZERS.		YIELD SHELLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
O.	Nothing,	—		8.5
A.	Nitrate of Soda, High Gr'de Blood * Muriate of Potash, Thomas Slag,	75 100 100 500		34.3
B.	Nit. Mixture, as A, Muriate of Potash, Thomas Slag,	175 100 600		45.1
C.	Nit. Mixture, as A, Muriate of Potash, Thomas Slag,	175 100 700		48.8
D.	Nit. Mixture, as A, Muriate of Potash, Thomas Slag,	175 50 500		46.8
E.	Nit. Mixture, as A, Muriate of Potash, Thomas Slag,	175 100 500		42.3
F.	Nit. Mixture, as A, Muriate of Potash, Thomas Slag,	175 150 500		38.2
G.	Pulverized Tankage, Muriate of Potash,	500 100		34.0
H.	Nit. Mixture, as A, Muriate of Potash, Dis. Bone-black,	175 100 500		42.8
M.	Manure,	—		42.9

* Nitrogen Mixture.

The soil of Mr. Day's field is a fine, light loam, with a subsoil much like the surface soil. In the previous soil tests the crop responded quite generally to all three of the ingredients (nitrogen, phosphoric acid and potash), although phosphoric acid exerted the most marked influence. In the test for 1890, the results appear to be considerably modified by irregularities in the soil of the different parts of the field. The yield on plots A, B, and C indicate a beneficial effect from large quantities of Thomas slag, but where the potash was increased and the slag kept constant, the yields were considerably lighter. It would not be safe to conclude from this one test, that potash is not needed on this soil. Phosphoric acid, however, seems to be the ingredient most needed. Plot M was fertilized with one-half cord of horse manure, harrowed in. It will be noticed that the yield of corn is the same as for the adjoining plot H. The yield of stover was 560 lbs. greater on the plot with manure. If we assume a value of $3 a cord for the horse manure, the cost would be at the rate of $15 per acre. Estimated on this basis, the cost of the fertilizer is considerably greater than that of the other plots. The field is more than a mile from the farm buildings, and hence the expense of getting the manure on to the land would be much greater than for the fertilizer. Commercial fertilizers can generally be used with greater profit than stable manure where the distance for hauling is great.

PRACTICAL DEDUCTIONS.

THE SEASON.

The season generally has a more marked effect on the crop than the soil has. The experiments are often greatly modified by unfavorable weather. The past season has been generally favorable for grass, corn, and potatoes. The drought was quite severe during July, but corn did not appear to suffer. Oats, however, were injured by "rust" during June, and this, together with the drought of the following month, seemed to hasten maturity, and cause a light, poorly filled seed.

POOR AND UNIFORM SOIL NEEDED.

For the field experiments with fertilizers, poor soils are selected wherever practicable. The object of such experiments is not to obtain large crops, but to get comparative results from the use of fertilizers, under conditions as uniform as it is practicable to obtain.

If the soil lacks uniformity, or has an abundance of available plant-food, it will be impossible to judge how much of the growth is due to the plant-food in the fertilizer applied, and how much to that previously stored in the soil. Just here is the chief difficulty with field experiments, and one that often makes the results very unreliable, unless they are carried through a series of years. It is almost impossible to find a field of one or two acres that is uniform throughout. Soils vary greatly as to the amounts of available plant-food they contain; as to the relative amounts of sand, clay, or humus present; as to fineness of texture, slope, powers of absorbing and retaining heat and moisture; and as to their powers of holding, in an available form, the fertilizing ingredients supplied. The subsoil also exerts a great and varying influence, especially in regulating the supply of moisture from ground water.

DIFFERENCES IN SOILS.

Connecticut soils, being of the drift formation, are very complex in their make-up. Little can be learned with regard to their composition by a study of the rocks. One soil may be made up largely of silica or quartz, while only a few rods away another may have been formed from feldspathic or potash containing rocks. Under these circumstances their natural fertility will vary greatly.

Chemical analysis of soils has not been found to be a satisfactory means of determining their fertility. It may show the composition of the particular sample analyzed, but it fails to indicate the amount of plant-food that may be available to the crop. It is also practically impossible to secure a sample that will represent the average of an entire field. In the so called "soil tests," the plant acts as its own chemist. By applying nitrogen, phosphoric acid, and potash, singly and in combinations, to different plots of land, we give the plant a chance to draw from the soil the ingredients not supplied. If any of the above constituents are already present in the soil in considerable quantities, the results in the crop will soon indicate it.

FERTILIZERS ADAPTED TO THE SOIL GIVE THE BEST RESULTS.

The largest yields are quite apt to occur where complete fertilizers are used. This has been the case in the majority of our experiments. As a rule, however, the best financial returns were not obtained from such mixtures. In Mr. Dean's experiment for the past two years, the largest crop has been given where only nitrogen and potash were applied, and in Mr. Hinman's experiment but very little increase resulted where phosphoric acid was added to these two ingredients. While in experiments in the Housatonic Valley, potash appeared to be the ingredient that regulated the yields to the greatest extent, in other localities phosphoric acid has proven of much greater importance. During the past two years, in experiments at South Manchester, Lebanon, Franklin, North Woodstock, and Danielsonville, phosphoric acid has played the most important part. In all of these cases, where it was omitted from the mixtures, the yields were but little if any larger than with no fertilizer. It would be wrong to conclude that the other ingredients did no good. They frequently did increase the yield when used with phosphoric acid.

THE RELATIVE IMPORTANCE OF PHOSPHORIC ACID AND POTASH.

Many soils have supplies of phosphoric acid and potash that can be drawn upon, year by year, without materially lessening their productiveness. The soils of the Housatonic Valley which have entered into the experiments seem to contain large quantities of phosphates, and to be lacking in potash. In many parts of the State, potash feldspar enters largely into the make-up of the soils, and hence they are generally quite well supplied with potash. Our system of farming has been such as to draw quite differently and irregularly upon the stores of plant-food in the soil. By raising live-stock, and disposing of it or its products, tons of phosphoric acid have been sold off the farm in bone, muscle, milk, and cheese. Phosphoric acid is used up in animal growth to a far greater degree than potash. This may in part account for the lack of phosphoric acid in many New England soils.

IMPORTANCE OF NITROGEN.

Nitrogen holds in plant life and in the economy of the farm, a very different position from phosphoric acid, potash, or lime. In the first place, it is the most costly ingredient; and, secondly, it is the most changeable and uncertain. We pay for it from two to three times as much as for either potash or phosphoric acid. At the same time it exists in abundance in the air, though for the most part, in the free state, *i. e.*, not combined with other elements. It is supplied to our soils as organic compounds, in dried blood, fish, etc., as salts of ammonia, or in the form of nitrates, but only in the latter form can plants utilize it to any very great extent. The other forms must be partly or entirely changed into nitrates before the plant can make use of them. These changes take place after the fertilizer is added to the soil.

In the more soluble forms of nitrogen, as nitrate of soda and sulphate of ammonia, it is necessary to exercise care to prevent loss, especially on light soils with open, porous subsoils. Such fertilizers should be applied when the crop is growing, or at a time when the plant will soon be in condition to utilize them.

There is little doubt to-day but what one of the cheapest and best ways of adding nitrogen to soils is to grow the "nitrogen collectors," as clover, alfalfa, cow peas, vetch, and lupines, and feed them and save the manure, or plough them under. Nitrogen may be thus supplied to the "nitrogen feeders," as wheat, oats, rye, root crops, potatoes, and possibly corn. Clover, vetch, or small varieties of peas, can be sown in the spring upon grain fields, and after the grain is harvested, they will produce a good crop for ploughing under late in the fall, or the clover may remain until the next spring.

The best financial results for corn are generally obtained where yard manures are depended upon as a source of nitrogen, and the special ingredient that is most lacking in the soil is supplied from some commercial product.

CONCLUSIONS.

Soils cannot be cultivated to the greatest profit without a knowledge of their deficiencies, as regards plant-food. Soil tests with fertilizers seem to be the best practical means for ascertaining these deficiencies in particular soils. But it must be remembered that the fertility of a given soil depends upon other things as well as upon the available supply of plant-food. Often lack of moisture is a more serious deficiency than the lack of plant-food.

The wide differences found in soils afford a strong argument in favor of home mixed fertilizers. The special needs of different soils cannot be considered by the manufacturer who prepares his fertilizers for general use. The farmer may, however, prepare such mixtures as will meet both the deficiencies of his soil and the requirements of his crops.

These experiments indicate that fertilizers should be so used as to supply, in liberal quantities, the ingredients that are found to be most lacking in the soil. The other forms of plant-food should be more sparingly added, considerable dependence being placed on the supply already in the soil.

TABLE 14.—SOIL TEST WITH FERTILIZERS ON CORN.

BY M. H. DEAN, FALLS VILLAGE.

No. of Plot.	Fertilizers Per Acre.			Yield Per Plot. 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % water		Stover.	Gain or Loss (-) over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
O.	Nothing, - -	—	—	15	24	132	1.6	2.3	1320	—
A.	Nitrate of Soda, -	320	7 92	55	72	199	5.9	7.0	1990	7.4
B.	Dis. Bone-black, -	640	8 80	16	34	147	1.7	3.3	1470	-.6
C.	Muriate of Potash, -	320	6 96	54	14	439	5.8	1.4	4390	1.6
D.	Nitrate of Soda, - Dis. Bone-black, -	320 640	16 96	100	64	230	10.8	6.2	2300	11.4
OO.	Nothing, - -	—	—	28	44	159	3.0	4.3	1590	—
E.	Nitrate of Soda, - Muriate of Potash, -	320 320	15 04	391	35	463	41.0	3.4	4630	38.8
F.	Dis. Bone-black, - Muriate of Potash, -	640 320	16 00	66	18	430	7.1	1.7	4300	3.2
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash, -	320 640 320	24 00	284	46	585	30.5	4.5	5850	29.4
G*a*.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash, -	320 1280 320	32 48	343	36	586	36.9	3.5	5860	34.8

TABLE 15.—SOIL TEST WITH FERTILIZERS ON CORN.

BY R. S. HINMAN, OXFORD (P. O., STEVENSON).

No. of Plot.	Fertilizers Per Acre.			Yield Per Plot. 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % water		Stover.	Gain or Loss (-) over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
A.	Nitrate of Soda, -	160	3 96	29	52	105	3.4	5.5	1050	-5.5
B.	Dis. Bone-black, -	320	4 40	68	46	111	7.9	4.8	1110	-1.7
C.	Muriate of Potash, -	160	3 48	131	40	151	15.2	4.2	1510	5.0
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320	8 48	87	65	146	10.1	6.8	1460	2.5
E.	Nitrate of Soda, - Muriate of Potash, -	160 160	7 52	256	45	219	29.8	4.7	2190	20.1
O.	Nothing, - -	—	—	70	60	162	8.1	6.3	1620	—
F.	Dis. Bone-black, - Muriate of Potash, -	320 160	8 00	202	49	154	23.5	5.2	1540	14.3
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash, -	160 320 160	12 00	316	26	307	36.7	2.7	3070	25.0
H.	Plaster, - -	400	1 70	85	43	139	9.9	4.5	1390	0
I.	Complete Fertilizer Varied forms,	600	—	206	30	297	24.0	3.2	2970	12.8

TABLE 16.—SOIL TEST WITH FERTILIZERS ON CORN.

By CLIFTON PECK, Franklin (P. O., Lebanon.)

No. of Plot.	Fertilizers Per Acre.			Yield Per Plot. 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % water		Stover.	Gain over Nothing Plot.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
A.	Nitrate of Soda, -	160	3 96	176	35	203	21.0	3.0	2030	10.0
B.	Dis. Bone-black, -	320	4 40	238	44	225	28.3	4.0	2250	18.3
C.	Muriate of Potash, -	160	3 48	170	39	240	20.2	3.3	2400	9.5
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320	8 48	211	48	213	25.1	4.2	2130	15.3
E.	Nitrate of Soda, - Muriate of Potash, -	160 160	7 52	154	31	235	18.3	2.6	2350	6.9
F.	Dis. Bone-black, - Muriate of Potash, -	320 160	8 00	241	27	224	28.7	2.3	2240	17.0
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash, -	160 320 160	12 00	215	32	223	25.6	2.7	2230	14.3
H.	Plaster, - - -	400	1 70	128	33	187	15.2	2.8	1870	4.0
00.	Nothing, - -	—	—	87	42	188	10.4	3.6	1880	—

TABLE 17.—SOIL TEST WITH FERTILIZERS ON CORN.

By C. E. MAY, East Woodstock.

No. of Plot.	Fertilizers Per Acre.			Yield Per Plot. 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % water		Stover.	Gain or Loss (-) over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
0.	Nothing, - -	—	—	348	17	271	43.9	1.9	2710	—
A.	Nitrate of Soda, -	160	3 96	401	12	276	50.6	1.4	2760	7.8
B.	Dis. Bone-black, -	320	4 40	313	8	249	39.5	.9	2490	-3.8
C.	Muriate of Potash, -	160	3 48	359	6	287	45.3	.7	2870	1.8
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320	8 48	428	10	330	54.0	1.1	3300	10.9
E.	Nitrate of Soda, - Muriate of Potash, -	160 160	7 52	427	6	303	53.8	.7	3030	10.3
F.	Dis. Bone-black, - Muriate of Potash, -	320 160	8 00	343	3	288	43.3	.3	2880	-.6
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash, -	160 320 160	12 00	450	6	375	56.7	.7	3750	13.2
H.	Plaster, - - -	400	1 70	346	11	259	43.6	1.2	2590	.6
00.	Nothing, - -	—	—	325	14	222	41.0	1.6	2220	—

TABLE 18.—SOIL TEST WITH FERTILIZERS ON CORN.

By THE STATION, MANSFIELD.

No. of Plot.	FERTILIZERS PER ACRE.			YIELD PER PLOT. 1-12 ACRE.			YIELD PER ACRE.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % water		Stover.	Gain over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
o.	Nothing, - -	—	—	176	32	158	24.6	4.3	1896	—
A.	Nitrate of Soda, -	160	3 96	206	28	167	28.7	3.7	2004	4.4
B.	Dis. Bone-black, -	320	4 40	221	19	171	30.8	2.5	2052	5.3
C.	Muriate of Potash, -	160	3 48	196	23	189	27.3	3.1	2268	2.4
oo.	Nothing, - -	—	—	165	28	153	23.0	3.7	1836	—
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320	8 48	238	22	199	33.2	2.9	2388	8.1
E.	Nitrate of Soda, - Muriate of Potash, -	160 160	7 52	214	22	201	29.9	2.9	2412	4.8
F.	Dis. Bone-black, - Muriate of Potash, -	320 160	8 00	224	23	216	31.3	3.1	2592	6.4
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash, -	160 320 160	12 00	248	21	236	34.6	2.8	2832	9.4
ooo.	Nothing, - -	—	—	175	31	159	24.4	4.1	1908	—
X.	Stable Manure, - Dis. Bone-black, -	12000 160	18 80	299	18	257	41.7	2.4	3084	16.1
Y.	Stable Manure, -	16000	19 20	289	25	269	40.3	3.3	3228	15.6

TABLE 19.

SPECIAL NITROGEN EXPERIMENT ON POTATOES.

BY M. H. DEAN, FALLS VILLAGE.

No. of Plot.	FERTILIZERS PER ACRE.			YIELD PER PLOT. 1-20 ACRE.			YIELD PER ACRE.			
	Kind.	Weight.	Cost.	Large.	Small.	Total.	Large.	Small.	Total.	Gain over Nothing Plots.
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Bu.	Bu.
0	Nothing, - - - -	—	—	281	78	359	93.7	26.0	120	—
	Nitrate of Soda Group.									
7	Mixed Minerals, as No. 6, Nitrate of Soda, - -	480 160	12 00	643	54	697	214.3	18.0	232	95
8	Mixed Minerals, as No. 6, Nitrate of Soda, - -	480 320	15 90	637	63	700	212.3	21.0	233	96
9	Mixed Minerals, as No. 6, Nitrate of Soda, - -	480 480	19 92	648	84	732	216.0	28.0	244	107
6*a*	Dis. Bone-blk. Mixed Mur. of Potash Min'rls.	320 160	8 00	582	96	678	194.0	32.0	226	89
	Sul. of Ammonia Group.									
10	Mixed Minerals, as No. 6, Sulphate of Ammonia, -	480 120	12 44	606	124	730	202.0	41.3	243	106
11	Mixed Minerals, as No. 6, Sulphate of Ammonia, -	480 240	16 88	569	109	678	189.7	36.3	226	89
12	Mixed Minerals, as No. 6, Sulphate of Ammonia, -	480 360	21 32	646	49	695	215.3	16.3	232	94
6*b*	Mixed Minerals, as No. 6,	480	8 00	578	53	631	192.7	17.7	210	73
	Dried Blood Group.									
13	Mixed Minerals, as No. 6, Dried Blood, - - -	480 200	11 95	578	75	653	192.7	25.0	218	81
14	Mixed Minerals, as No. 6, Dried Blood, - - -	480 400	15 90	578	76	654	192.7	25.3	218	81
15	Mixed Minerals, as No. 6, Dried Blood, - - -	480 600	19 85	545	80	625	181.7	26.7	208	71
00	Nothing, - - - -	—	—	392	72	464	130.7	24.0	155	—

TABLE 20.

SPECIAL NITROGEN EXPERIMENT ON OATS.

BY G. A. ROSS, JEWETT CITY.

No. of Plot.	Fertilizers Per Acre.			Yield Per Plot. 1-16 Acre.		Yield Per Acre.			
	Kind.	Weight.	Cost.	Oats.	Straw.	Oats.	Straw.	Bushels per Acre.	Gain over Nothing Plots.
		Lbs.	$	Lbs.	Lbs.	Lbs.	Lbs.	Bu.	Bu.
0.	Nothing, - - - - -	—	—	7.5	11.5	120	184	3.8	—
	Nitrate of Soda Group.								
7.	Mixed Minerals, as 6*a*, - Nitrate of Soda, - -	480 160	12 00	32.0	62.5	512	1000	16.0	13
8.	Mixed Minerals, as 6*a*, - Nitrate of Soda, - -	480 320	15 90	37.0	80.5	592	1288	18.5	16
9.	Mixed Minerals, as 6*a*, - Nitrate of Soda, - -	480 480	19 92	44.5	94.0	712	1504	22.3	19
6*a*.	Dis. Bone-blk. Mixed Mur. of Potash Minr'ls	320 160	8 00	19.0	32.0	292	512	9.5	7
00.	Nothing, - - - - -	—	—	3.5	8.0	56	128	1.8	—
	Sul. of Ammonia Group.								
10.	Mixed Minerals, as 6*a*, - Sulphate of Ammonia, -	480 120	12 44	22.0	54.0	352	864	11.0	8
11.	Mixed Minerals, as 6*a*, - Sulphate of Ammonia, -	480 240	16 88	27.5	56.5	440	904	13.8	11
12.	Mixed Minerals, as 6*a*, - Sulphate of Ammonia, -	480 360	21 32	33.5	84.5	536	1352	16.8	14
6*b*.	Mixed Minerals, - -	480	8 00	24.0	36.0	384	576	12.0	9
	Dried Blood Group.								
13.	Mixed Minerals, as 6*a*, - Dried Blood, - - -	480 200	11 95	27.0	52.5	432	840	15.5	13
14.	Mixed Minerals, as 6*a*, - Dried Blood, - - -	480 400	15 90	29.0	61.0	464	976	14.5	12
15.	Mixed Minerals, as 6*a*, - Dried Blood, - - -	480 600	19 85	39.0	101.0	624	1616	19.5	17
000.	Nothing, - - - -	—	—	6.5	16.5	102	264	3.3	—

TABLE 21.

SPECIAL CORN EXPERIMENT.

BY K. B. LOOMIS, SOUTH MANCHESTER.

No. of Plot.	FERTILIZERS PER ACRE.			YIELD PER PLOT. 1-10 ACRE.			YIELD PER ACRE.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % water		Stover.	Gain over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
O.	Nothing, - -	—	—	123	100	225	13.1	8.1	2250	—
A.	Nitrate of Soda High Gr. Blood * Muriate of Potash, - Thomas Slag, -	75 100 100 500	11 18	452	39	395	48.1	3.2	3950	25.7
B.	Nit'gen Mixt., like A, Muriate of Potash, - Thomas Slag, -	175 100 600	12 18	438	43	384	46.6	3.5	3840	24.5
C.	Nit'gen Mixt., like A, Muriate of Potash, - Thomas Slag, -	175 100 700	13 18	476	35	391	50.6	2.8	3910	27.8
D.	Nit'gen Mixt., like A, Thomas Slag, - Muriate of Potash, -	175 500 50	10 08	460	38	357	48.9	3.1	3570	26.4
E.	Nit'gen Mixt., like A, Thomas Slag, - Muriate of Potash, -	175 500 100	11 18	482	34	384	51.3	2.8	3840	28.5
F.	Nit'gen Mixt., like A, Thomas Slag, - Muriate of Potash, -	175 500 150	12 28	519	38	449	55.2	3.1	4490	32.7
G.	Pulv. Tankage, - Muriate of Potash, -	500 100	12 20	505	38	456	53.7	3.1	4560	31.2
H.	Nit'gen Mixt., like A, Muriate of Potash, - Dis. Bone-black, -	175 100 500	13 18	555	30	626	59.0	2.4	6260	35.8
OO.	Nothing, - -	—	—	213	89	269	22.7	7.2	2690	—

* Nitrogen Mixture.

TABLE 22.

SPECIAL CORN EXPERIMENT.

By J. H. TUCKER, LEBANON.

No. of Plot.	Fertilizers Per Acre.			Yield Per Plot. 1–10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % water		Stover.	Gain over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
0.	Nothing, - -	—	—	65	133	198	7.8	15.1	1980	—
A.	Nitrate of Soda High Gr. Blood * Muriate of Potash, - Thomas Slag, -	75 100 100 500	11 18	229	84	240	27.6	9.5	2400	15.3
B.	Nit'gen Mixt., like A, Muriate of Potash, - Thomas Slag, -	175 100 600	12 18	236	102	298	28.4	11.6	2980	18.2
C.	Nit'gen Mixt., like A, Muriate of Potash, - Thomas Slag, -	175 100 700	13 18	233	132	328	28.1	15.0	3280	21.3
D.	Nit'gen Mixt., like A, Thomas Slag, - Muriate of Potash, -	175 500 50	10 08	197	140	291	23.7	15.9	2910	17.8
E.	Nit'gen Mixt., like A, Thomas Slag, - Muriate of Potash, -	175 500 100	11 18	157	144	271	18.9	16.4	2710	13.5
F.	Nit'gen Mixt., like A, Thomas Slag, - Muriate of Potash, -	175 500 150	12 28	182	130	297	21.9	14.8	2970	14.9
G.	Pulv. Tankage, - Muriate of Potash, -	500 100	12 20	186	130	290	22.4	14.8	2900	15.4
H.	Nit'gen Mixt., like A, Muriate of Potash, - Dis. Bone-black, -	175 100 500	13 18	306	74	316	36.9	8.4	3160	23.5
00.	Nothing, - -	—	—	64	114	200	7.7	12.9	2000	—

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* Nitrogen Mixture.

TABLE 23.

SPECIAL CORN EXPERIMENT,

BY L. H. HEALEY, NORTH WOODSTOCK.

No. of Plot.	FERTILIZERS PER ACRE.			YIELD PER PLOT. 1-10 ACRE.			YIELD PER ACRE.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % water		Stover.	Gain over Nothing Plot.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
O.	Nothing, - -	—	—	315	11	262	38.4	1.2	2620	—
A.	Nitrate of Soda } * High Gr. Blood } Muriate of Potash, - Thomas Slag, -	75 100 100 500	11 18	361	23	332	44.0	2.5	3320	6.9
B.	Nit'gen Mixt., like A, Muriate of Potash, - Thomas Slag, -	175 100 600	12 18	414	13	376	50.5	1.4	3760	12.3
C.	Nit'gen Mixt., like A, Muriate of Potash, - Thomas Slag, -	175 100 700	13 18	405	10	334	49.4	1.1	3340	10.9
D.	Nit'gen Mixt., like A, Thomas Slag, - Muriate of Potash, -	175 500 50	10 08	397	14	372	48.4	1.5	3720	10.3
E.	Nit'gen Mixt., like A, Thomas Slag, - Muriate of Potash, -	175 500 100	11 18	419	19	347	51.1	2.1	3470	13.6
F.	Nit'gen Mixt., like A, Thomas Slag, - Muriate of Potash, -	175 500 150	12 28	441	11	407	53.8	1.2	4070	15.4
G.	Pulv. Tankage, - Muriate of Potash, -	500 100	12 20	387	7	354	47.2	1.0	3540	8.6
H.	Nit'gen Mixt., like A, Muriate of Potash, - Dis. Bone-black, -	175 100 500	13 18	397	12	406	48.4	1.3	4060	10.1

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* Nitrogen Mixture.

Table 24.

SPECIAL CORN EXPERIMENT.

By FRANK DAY, Danielsonville.

No. of Plot.	Fertilizers Per Acre.			Yield Per Plot. 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % water		Stover.	Gain over Nothing Plot.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
O.	Nothing, -	—	—	40	32	66	5.0	3.5	660	—
A.	Nitrate of Soda High Gr. Blood * Muriate of Potash, - Thomas Slag, -	75 100 100 500	11 18	253	25	226	31.6	2.7	2260	25.8
B.	Nit'gen Mixt., like A, Muriate of Potash, - Thomas Slag, -	175 100 600	12 18	344	19	254	43.0	2.1	2540	36.6
C.	Nit'gen Mixt., like A, Muriate of Potash, - Thomas Slag, -	175 100 700	13 18	378	14	224	47.3	1.5	2240	40.3
D.	Nit'gen Mixt., like A, Thomas Slag, - Muriate of Potash, -	175 500 50	10 08	357	20	193	44.6	2.2	1930	38.3
E.	Nit'gen Mixt., like A, Thomas Slag, - Muriate of Potash, -	175 500 100	11 18	327	13	188	40.9	1.4	1880	33.8
F.	Nit'gen Mixt., like A, Thomas Slag, - Muriate of Potash, -	175 500 150	12 28	288	20	170	36.0	2.2	1700	29.7
G.	Pulv. Tankage, - Muriate of Potash, -	500 100	12 20	256	18	144	32.0	2.0	1440	25.5
H.	Nit'gen Mixt., like A, Muriate of Potash, - Dis. Bone-black, -	175 100 500	13 18	325	20	170	40.6	2.2	1700	34.3
M.	Manure, - -	—	—	325	21	226	40.6	2.3	2260	34.4

* Nitrogen Mixture.

EFFECTS OF DIFFERENT FERTILIZERS UPON THE COMPOSITION OF OATS AND STRAW.

BY

CHAS. D. WOODS AND H. B. GIBSON.

In connection with the studies of the effects of kinds and amounts of fertilizers upon the composition of the maize plant and of the grasses, analyses were made of the oats and straw grown in a "special nitrogen" experiment.

The investigation was undertaken with the hope of adding to the knowledge of the effects of different fertilizers upon the percentage composition, and upon the total yield of nutritive ingredients of grain and straw of the oat plant, with special reference to the effect of nitrogenous fertilizers upon the amounts of protein.

The experiment from which the samples were taken was conducted for the Station by Mr. G. A. Ross, of Jewett City, and is described on pages 73 and 74 of this Report, and may be summed up as follows: The soil is an alluvial formation, a light sandy loam, with a sandy subsoil. The crop appeared to be slightly affected by drought during July. There was quite an increase from the use of mixed minerals, and a still greater increase wherever nitrogen was applied. Unlike what is generally observed in corn experiments of this class, the oats responded quite decidedly to nitrogen. In all of the nitrogen groups, there was a gradual increase in the yields of both grain and straw, as the quantities of nitrogen used were increased.

Quite large samples, representing the yield as fairly as practicable, were taken by the Station Agriculturist at the time of harvest. The oats had been cut for some time before harvesting, and were, as the results of the analyses show, quite dry when the field weighings were made and samples taken. The crop from each plot was threshed separately at harvest, and the samples were selected immediately after threshing. The samples were weighed, placed in cotton bags and immediately shipped to the laboratory. On receipt, they were again weighed, thereby checking the field weights.

The methods of analyses adopted by the Association of Official Agricultural Chemists in August, 1890, were used in the work.

The results of the analyses are given in the tables which follow. Beyond the tables, a brief discussion of these results will be found.

TABLE 25.

SPECIAL NITROGEN EXPERIMENT WITH OATS.

By G. A. ROSS.

Proximate Composition of Water-free Substance of Oats.

Plot Number.	FERTILIZERS.	Laboratory Number.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Nitrogen.
			%	%	%	%	%	%
0	Unmanured, - - -	837	14.25	5.48	62.52	14.33	3.42	2.28
00	Unmanured, - - -	839	13.60	5.63	62.75	14.61	3.41	2.17
000	Unmanured, - - -	841	13.12	5.47	62.42	15.96	3.03	2.10
	Average of unmanured, -	—	13.66	5.53	62.56	14.96	3.29	2.18
6a	Dis. Bone-blk. Mixed Mur. of Potash Min'rls.	843	14.38	5.63	63.57	13.22	3.20	2.30
6b	Mixed Minerals, as *6a*, -	845	14.25	5.93	65.19	11.81	2.82	2.28
	Average Mixed Minerals,	—	14.31	5.78	64.38	12.52	3.01	2.29
	Nitrate of Soda Group—							
7	Mixed Minerals, as *6a*, Nit. Soda, 25 lbs. Nit'gen,	847	15.70	6.22	65.10	10.13	2.85	2.51
8	Mixed Minerals, as *6a*, Nit. Soda, 50 lbs. Nit'gen,	849	16.31	6.03	64.52	10.49	2.65	2.61
9	Mixed Minerals, as *6a*, Nit. Soda, 75 lbs. Nit'gen,	851	16.75	6.14	63.72	10.74	2.65	2.68
	Sulph. Ammonia Group—							
10	Mixed Minerals, as *6a*, Sul. Am., 25 lbs. Nit'gen,	853	13.94	6.05	64.90	12.25	2.86	2.23
11	Mixed Minerals, as *6a*, Sul. Am., 50 lbs. Nit'gen,	855	15.12	6.14	64.45	11.59	2.70	2.42
12	Mixed Minerals, as *6a*, Sul. Am., 75 lbs. Nit'gen,	857	15.00	5.86	62.38	13.84	2.92	2.40
	Dried Blood Group—							
13	Mixed Minerals, as *6a*, Dr. Blood, 25 lbs. Nit'gen,	859	14.50	6.00	64.85	11.88	2.77	2.32
14	Mixed Minerals, as *6a*, Dr. Blood, 50 lbs. Nit'gen,	861	14.06	5.85	65.22	12.13	2.74	2.25
15	Mixed Minerals, as *6a*, Dr. Blood, 75 lbs. Nit'gen,	863	14.69	5.98	64.91	11.74	2.68	2.35
	Minimum, - - -	—	13.12	5.47	62.38	10.13	2.65	2.10
	Maximum, - - -	—	16.25	6.22	65.22	15.96	3.42	2.68
	Average of all, - -	—	**14.69**	**5.89**	**64.03**	**12.48**	**2.91**	**2.35**
	Average of Nit'gen Plots,	—	**15.12**	**6.03**	**64.45**	**11.64**	**2.76**	**2.42**

TABLE 26.

SPECIAL NITROGEN EXPERIMENT WITH OATS.

By G. A. ROSS.

Proximate Composition of Water-free Substance of Straw.

Plot Number.	FERTILIZERS.	Laboratory Number.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Nitrogen.
			%	%	%	%	%	%
0	Unmanured, - - -	836	8.63	3.90	48.21	34.49	4.77	1.38
00	Unmanured, - - -	838	8.31	3.09	48.99	35.26	4.35	1.33
000	Unmanured, - - -	840	9.00	3.44	48.67	34.71	4.18	1.44
	Average of unmanured, -	—	8.65	3.48	48.62	34.82	4.43	1.38
6*a*	Dis. Bone-blk. } Mixed Mur. of Potash } Min'rls.	842	6.13	3.40	48.35	37.15	4.97	.98
6*b*	Mixed Minerals, as 6*a*, -	844	5.94	3.42	49.04	37.31	4.29	.95
	Average Mixed Minerals,	—	6.04	3.41	48.69	37.23	4.63	.97
	Nitrate of Soda Group—							
7	Mixed Minerals, as 6*a*, Nit. Soda, 25 lbs. Nit'gen,	846	5.06	3.84	47.82	38.52	4.76	.81
8	Mixed Minerals, as 6*a*, Nit. Soda, 50 lbs. Nit'gen,	848	5.25	3.32	48.29	38.49	4.65	.84
9	Mixed Minerals, as 6*a*, Nit. Soda, 75 lbs. Nit'gen,	850	6.00	3.56	47.23	38.19	5.02	.96
	Sulph. Ammonia Group—							
10	Mixed Minerals, as 6*a*, Sul. Am., 25 lbs. Nit'gen,	852	5.69	3.60	49.56	36.61	4.52	.91
11	Mixed Minerals, as 6*a*, Sul. Am., 50 lbs. Nit'gen,	854	6.81	3.38	48.66	37.00	4.15	1.09
12	Mixed Minerals, as 6*a*, Sul. Am., 75 lbs. Nit'gen,	856	7.50	3.18	48.15	37.05	4.12	1.20
	Dried Blood Group—							
13	Mixed Minerals, as 6*a*, Dr. Blood, 25 lbs. Nit'gen,	858	5.63	3.19	48.52	38.27	4.39	.90
14	Mixed Minerals, as 6*a*, Dr. Blood, 50 lbs. Nit'gen,	860	5.25	3.17	48.95	38.12	4.51	.84
15	Mixed Minerals, as 6*a*, Dr. Blood, 75 lbs. Nit'gen,	862	5.38	3.19	48.86	38.12	4.45	.86
	Minimum, - - -	—	5.06	3.09	47.23	34.49	4.12	.81
	Maximum, - - -	—	9.00	3.90	49.56	38.52	5.02	1.44
	Average of all, - -	—	**6.47**	**3.41**	**48.52**	**37.09**	**4.51**	**1.04**
	Average of Nit'gen Plots,	—	**5.84**	**3.38**	**48.45**	**37.82**	**4.51**	**.93**

TABLE 27.

SPECIAL NITROGEN EXPERIMENT WITH OATS.

BY G. A. ROSS.

Proximate Composition of Oats, Calculated to Water Content at Harvest.

Plot Number.	FERTILIZERS.	Laboratory Number.	Water.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			%	%	%	%	%	%
0	Unmanured, - - -	837	15.14	12.09	4.65	53.06	12.16	2.90
00	Unmanured, - - -	839	13.25	11.78	4.89	54.44	12.68	2.96
0c0	Unmanured, - - -	841	14.55	11.21	4.66	53.34	13.64	2.60
	Average of unmanured, -	—	14.31	11.69	4.73	53.61	12.83	2.83
6*a*	Dis. Bone-blk. } Mixed Mur. of Potash } Min'rls,	843	16.44	12.01	4.71	53.13	11.04	2.67
6*b*	Mixed Minerals, as 6*a*, -	845	15.51	12.04	5.00	55.09	9.98	2.38
	Average Mixed Minerals,	—	15.97	12.02	4.86	54.11	10.51	2.53
	Nitrate of Soda Group—							
7	Mixed Minerals, as 6*a*, Nit. Soda, 25 lbs. Nit'gen,	847	15.96	13.19	5.23	54.70	8.52	2.40
8	Mixed Minerals, as 6*a*, Nit. Soda, 50 lbs. Nit'gen,	849	15.44	13.79	5.10	54.56	8.87	2.24
9	Mixed Minerals, as 6*a*, Nit. Soda, 75 lbs. Nit'gen,	851	16.19	14.04	5.15	53.40	9.00	2.22
	Sulph. Ammonia Group—							
10	Mixed Minerals, as 6*a*, Sul. Am., 25 lbs. Nit'gen,	853	13.27	12.09	5.25	56.29	10.62	2.48
11	Mixed Minerals, as 6*a*, Sul. Am., 50 lbs. Nit'gen,	855	13.56	13.07	5.31	55.72	10.00	2.34
12	Mixed Minerals, as 6*a*, Sul. Am., 75 lbs. Nit'gen,	857	15.50	12.67	4.95	52.72	11.69	2.47
	Dried Blood Group—							
13	Mixed Minerals, as 6*a*, Dr. Blood, 25 lbs. Nit'gen,	859	15.86	12.20	5.05	54.56	10.00	2.33
14	Mixed Minerals, as 6*a*, Dr. Blood, 50 lbs. Nit'gen,	861	12.97	12.24	5.09	56.76	10.55	2.39
15	Mixed Minerals, as 6*a*, Dr. Blood, 75 lbs. Nit'gen,	863	14.30	12.59	5.12	55.62	10.07	2.30
	Minimum, - - -	—	12.97	11.21	4.65	52.72	8.52	2.22
	Maximum, - - -	—	16.44	14.04	5.31	56.76	13.64	2.96
	Average of all, - -	—	**14.85**	**12.50**	**5.01**	**54.53**	**10.63**	**2.48**
	Average of Nit'gen Plots,	—	**14.78**	**12.88**	**5.14**	**54.93**	**9.92**	**2.35**

TABLE 28.

SPECIAL NITROGEN EXPERIMENT WITH OATS.

BY G. A. ROSS.

Proximate Composition of Straw, Calculated to Water Content at Harvest.

Plot Number.	FERTILIZERS.	Laboratory Number.	Water.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			%	%	%	%	%	%
0	Unmanured, - - -	836	10.45	7.73	3.49	43.16	30.90	4.27
00	Unmanured, - - -	838	11.14	7.38	2.75	43.53	31.33	3.87
000	Unmanured, - - -	840	16.02	7.56	2.89	40.87	29.15	3.51
	Average of unmanured, -	—	12.54	7.56	3.04	42.52	30.46	3.88
6*a*	Dis. Bone-blk. Mur. of Potash Mixed Min'rls.	842	12.53	5.36	2.98	42.29	32.48	4.36
6*b*	Mixed Minerals, as 6*a*, -	844	14.82	5.06	2.91	41.78	31.78	3.65
	Average Mixed Minerals,	—	13.67	5.21	2.95	42.03	32.13	4.01
	Nitrate of Soda Group—							
7	Mixed Minerals, as 6*a*, Nit. Soda, 25 lbs. Nit'gen,	846	14.34	4.34	3.29	40.96	32.99	4.08
8	Mixed Minerals, as 6*a*, Nit. Soda, 50 lbs. Nit'gen,	848	13.74	4.54	2.86	41.66	33.19	4.01
9	Mixed Minerals, as 6*a*, Nit. Soda, 75 lbs. Nit'gen,	850	13.77	5.16	3.06	40.75	32.93	4.33
	Sulph. Ammonia Group—							
10	Mixed Minerals, as 6*a*, Sul. Am., 25 lbs. Nit'gen,	852	14.75	4.85	3.07	42.25	31.31	3.87
11	Mixed Minerals, as 6*a*, Sul. Am., 50 lbs. Nit'gen,	854	13.77	5.87	2.91	41.96	31.91	3.58
12	Mixed Minerals, as 6*a*, Sul. Am., 75 lbs. Nit'gen,	856	14.28	6.43	2.72	41.28	31.76	3.53
	Dried Blood Group—							
13	Mixed Minerals, as 6*a*, Dr. Blood, 25 lbs. Nit'gen,	858	14.74	4.80	2.72	41.37	32.63	3.74
14	Mixed Minerals, as 6*a*, Dr. Blood, 50 lbs. Nit'gen,	860	13.69	4.53	2.74	42.25	32.90	3.89
15	Mixed Minerals, as 6*a*, Dr. Blood, 75 lbs. Nit'gen,	862	14.25	4.61	2.73	41.90	32.69	3.82
	Minimum, - - -	—	10.45	4.34	2.72	40.75	29.15	3.51
	Maximum, - - -	—	16.02	7.73	3.49	43.53	33.19	4.36
	Average of all, - -	—	**13.73**	**5.59**	**2.94**	**41.86**	**31.98**	**3.89**
	Average of Nit'gen Plots,	—	**14.15**	**5.01**	**2.90**	**41.59**	**32.48**	**3.89**

TABLE 29.

SPECIAL NITROGEN EXPERIMENT WITH OATS.

BY G. A. ROSS.

Proximate Ingredients in Oats per Acre.

Plot Number.	FERTILIZERS.	Laboratory Number.	Water-free Oats.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0	Unmanured, - - -	837	102	14.5	5.6	63.8	14.6	3.5
00	Unmanured, - - -	839	49	6.7	2.8	30.8	7.2	1.7
000	Unmanured, - - -	841	87	11.4	4.8	54.3	13.9	2.6
	Average of unmanured, -	—	79	10.8	4.4	49.4	11.8	2.6
6*a*	Dis. Bone-blk. Mixed Mur.of Potash Min'rls.	843	254	36.5	14.3	161.5	33.6	8.1
6*b*	Mixed Minerals, as 6*a*, -	845	324	46.2	19.2	211.2	38.3	9.1
	Average Mixed Minerals,	—	289	41.4	16.8	186.2	36.0	8.6
	Nitrate of Soda Group—							
7	Mixed Minerals, as 6*a*, Nit.Soda, 25 lbs. Nit'gen,	847	430	67.5	26.7	279.9	43.6	12.3
8	Mixed Minerals, as 6*a*, Nit.Soda, 50 lbs. Nit'gen,	849	501	81.7	30.2	323.2	52.6	13.3
9	Mixed Minerals, as 6*a*, Nit.Soda, 75 lbs. Nit'gen,	851	597	99.9	36.7	380.5	64.1	15.8
	Sulph. Ammonia Group—							
10	Mixed Minerals, as 6*a*, Sul.Am., 25 lbs. Nit'gen,	853	305	42.5	18.5	197.9	37.4	8.7
11	Mixed Minerals, as 6*a*, Sul.Am., 50 lbs. Nit'gen,	855	380	57.5	23.3	245.0	44.0	10.2
12	Mixed Minerals, as 6*a*, Sul.Am., 75 lbs. Nit'gen,	857	453	68.0	26.5	282.6	62.7	13.2
	Dried Blood Group—							
13	Mixed Minerals, as 6*a*, Dr.Blood, 25 lbs. Nit'gen,	859	364	52.8	21.8	236.1	43.3	10.0
14	Mixed Minerals, as 6*a*, Dr.Blood, 50 lbs. Nit'gen,	861	404	56.8	23.6	263.5	49.0	11.1
15	Mixed Minerals, as 6*a*, Dr.Blood, 75 lbs. Nit'gen,	863	535	78.6	32.0	347.3	62.8	14.3

TABLE 30.

SPECIAL NITROGEN EXPERIMENT WITH OATS.

BY G. A. ROSS.

Proximate Ingredients in Straw per Acre.

Plot Number.	FERTILIZERS.	Laboratory Number.	Water-free Straw.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0	Unmanured, - - -	836	165	14.2	6.4	79.5	57.0	7.9
00	Unmanured, - - -	838	114	9.5	3.5	55.9	40.2	5.0
000	Unmanured, - - -	840	222	20.0	7.6	108.0	77.1	9.3
	Average of unmanured, -	—	167	14.6	5.8	81.1	58.1	7.4
6*a*	Dis. Bone-blk. Mur.of Potash } Mixed Min'rls.	842	448	27.5	15.2	216.6	166.4	22.3
6*b*	Mixed Minerals, as 6*a*, -	844	491	29.2	16.8	240.8	183.2	21.0
	Average Mixed Minerals,	—	470	28.4	16.0	228.9	175.0	21.7
	Nitrate of Soda Group—							
7	Mixed Minerals, as 6*a*, Nit.Soda, 25 lbs.Nit'gen,	846	857	43.4	32.9	409.8	330.1	40.8
8	Mixed Minerals, as 6*a*, Nit.Soda, 50 lbs.Nit'gen,	848	1111	58.3	36.9	536.5	427.6	51.7
9	Mixed Minerals, as 6*a*, Nit.Soda, 75 lbs.Nit'gen,	850	1297	77.8	46.2	612.5	495.4	65.1
	Sulph. Ammonia Group—							
10	Mixed Minerals, as 6*a*, Sul.Am., 25 lbs. Nit'gen,	852	737	41.9	26.5	365.3	269.6	33.5
11	Mixed Minerals, as 6*a*, Sul.Am., 50 lbs. Nit'gen,	854	780	53.1	26.4	379.6	288.6	32.3
12	Mixed Minerals, as 6*a*, Sul.Am., 75 lbs. Nit'gen,	856	1159	86.9	36.9	558.0	429.4	47.8
	Dried Blood Group—							
13	Mixed Minerals, as 6*a*, Dr.Blood, 25 lbs. Nit'gen,	858	716	40.3	22.9	347.4	274.0	31.4
14	Mixed Minerals, as 6*a*, Dr.Blood, 50 lbs. Nit'gen,	860	842	44.2	26.7	412.4	321.1	37.9
15	Mixed Minerals, as 6*a*, Dr.Blood, 75 lbs. Nit'gen,	862	1249	67.2	39.8	610.4	476.0	55.6

TABLE 31.

SPECIAL NITROGEN EXPERIMENT WITH OATS.

By G. A. ROSS.

Yield per Acre in Pounds.

Plot Number.	Fertilizers.	Weight of one Bushel of Oats.	Harvest Weights.		Wts. from Analysis. Oats and Straw.			
			Oats.	Straw.	Water-free Substance.	Protein.	Fat.	Nitrogen-free Extract.
			Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0	Unmanured, - - -	22.0	120	184	267	29	12	143
00	Unmanured, - - -	—	56	128	163	16	6	87
000	Unmanured, - - -	23.3	102	264	309	31	12	162
	Average of unmanured, -	22.8	93	192	246	25	10	131
6*a*	Dis. Bone-blk. Mixed Mur. of Potash Min'rls.	28.3	304	512	702	64	30	378
6*b*	Mixed Minerals, as 6*a*, -	28.6	384	576	815	75	36	452
	Average Mixed Minerals,	28.5	344	544	759	70	33	415
	Nitrate of Soda Group—							
7	Mixed Minerals, as 6*a*, Nit. Soda, 25 lbs. Nit'gen,	31.5	512	1000	1287	111	60	690
8	Mixed Minerals, as 6*a*, Nit. Soda, 50 lbs. Nit'gen,	31.7	592	1288	1612	140	67	860
9	Mixed Minerals, as 6*a*, Nit. Soda, 75 lbs. Nit'gen,	31.0	712	1504	1894	178	83	993
	Sulph. Ammonia Group—							
10	Mixed Minerals, as 6*a*, Sul. Am., 25 lbs. Nit'gen,	29.0	352	864	1042	84	45	563
11	Mixed Minerals, as 6*a*, Sul. Am., 50 lbs. Nit'gen,	28.7	440	904	1160	111	50	625
12	Mixed Minerals, as 6*a*, Sul. Am., 75 lbs. Nit'gen,	24.5	536	1352	1612	155	63	841
	Dried Blood Group—							
13	Mixed Minerals, as 6*a*, Dr. Blood, 25 lbs. Nit'gen,	28.4	432	840	1080	93	45	584
14	Mixed Minerals, as 6*a*, Dr. Blood, 50 lbs. Nit'gen,	28.8	464	976	1246	101	50	676
15	Mixed Minerals, as 6*a*, Dr. Blood, 75 lbs. Nit'gen,	29.3	624	1456	1784	146	72	958

COMPOSITION OF THE OATS.

The oats compare favorably in proximate composition with the analyses of other American oats, and in most respects seem to be better than the specimens of Connecticut grown oats previously analyzed. The composition of American oats as given below is taken from the Report of the Connecticut Station for 1888. The figures there given have been calculated to water-free substance.

Percentage Composition of Water-free Substance of Oats.

	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
	%	%	%	%	%
Connecticut oats, 7 analyses,* - - -	10.47	5.94	69.11	11.17	3.31
American oats, 25 analyses,* - - -	12.78	5.40	67.43	11.06	3.33
Reported herewith—					
Minimum, - - - - - -	13.12	5.47	62.38	10.13	2.65
Maximum, - - - - - -	16.25	6.22	65.22	15.96	3.42
Average of all, - - - - - -	14.69	5.89	64.03	12.48	2.91
Average of oats grown with nitrogenous fertilizers, - - - -	15.12	6.03	64.45	11.64	2.76

*Report Conn. Station, 1888.

The higher percentage of protein in the oats from this experiment, and even in those from the unfertilized plots, is very noticeable. The average of all the samples shows 4.2 per cent., and the average of the oats from the plots supplied with nitrogenous fertilizers, 4.6 per cent. more protein in these than is found in the average of the other Connecticut grown oats. The average percentage of fat is about the same in these as found in the average of the other Connecticut grown oats. That the nitrogen-free extract is smaller is to be expected, since it is found by difference, (*i. e.*, by subtracting the sum of the percentages of protein, fat, fiber, and ash from 100 per cent.,) and the higher percentage of protein and fiber would necessarily make this difference smaller. The high percentage of fiber would seem to indicate that these oats had relatively a larger amount of husks (glumes). A high percentage of fiber together with a low weight of oats per bushel (as in the oats from the unmanured plots), doubtless indicates an inferior quality of oats. It will be noted that the percentages of fiber in the oats from most of the plots supplied with nitrogenous fertilizers are lower than the average found in Connecticut grown oats. It will be observed that the percentages of fiber in the oats from the plots of the nitrate of soda group are lower than that of Connecticut grown oats. It will also be observed from Table 31 that the oats from these plots were heavier than those from the other plots.

WEIGHT OF OATS AND AMOUNT OF FIBER.

Relation Between the Percentage of Fiber in the Oats and the Weight per Bushel.

Number of Plots.	Percentages of Fiber.	Weight of One Bushel of Oats.
0, 00, and 000, - - -	15.0	22.8 lbs.
12, - - - - -	13.8	24.5 lbs.
6*a*, 6*b*, 10, 11, 13, 14, and 15,	12.5 to 11.5	28.4 to 29.3, av. 28.8 lbs.
7, 8, and 9, - - -	10.7 to 10.1	31.0 to 31.7, av. 31.4 lbs.

That light weight oats should contain large percentages of fiber would be expected, and in this experiment there is evidently a relation between the percentage of fiber and the weight of oats, the percentage of fiber decreasing as the oats increase in weight. It will be noted (Table 31, first column) that the oats from plots 7, 8, and 9 weighed about 31.5 lbs. to the bushel, and were probably heavier than the average of Connecticut grown oats, and it will also be observed (see Table 25) that the percentages of fiber were about 10.5 or more than one-half per cent. below the average of 7 samples of Connecticut grown oats.

RELATION BETWEEN NITROGEN APPLIED IN FERTILIZER AND PROTEIN (NITROGEN × 6.25) FOUND IN CROP.

Percentages of Protein in Water-free Substance of Oats and of Straw.

Fertilizers.	Oats.			Straw.		
	Nitrate of Soda Group.	Sulphate of Ammonia Group	Dried Blood Group.	Nitrate of Soda Group.	Sulphate of Ammonia Group	Dried Blood Group.
	%	%	%	%	%	%
Mxd. Minerals and 25 lbs. Nit'gen,	15.7	13.9	14.5	5.1	5.7	5.6
Mxd. Minerals and 50 lbs. Nit'gen,	16.3	15.1	14.1	5.3	6.8	5.3
Mxd. Minerals and 75 lbs. Nit'gen,	16.8	15.0	14.7	6.0	7.5	5.4

The above table shows the percentages of protein found in the crops from the plots to which nitrogen was added in different forms and amounts.

In the nitrate of soda group there is a direct response to the amount of nitrogen supplied, the percentage of protein increasing one-half per cent. with each 25 lbs. of nitrogen added in the fertilizer. There was also a constant, though smaller, increase of the percentage of protein in the straw. There is a marked increase in the percentage of protein in oats and straw from plots supplied with varying amounts of sulphate of ammonia, except in the oats from the plot (12) having 75 lbs. of nitrogen to the acre. For some reason the oats on this plot were poor, weighing only 24.5 lbs. to the bushel, while oats from the other plots to which sulphate of ammonia was applied weighed 29 lbs. to the bushel. The fertilizer seems to have had a decided effect upon the percentage of protein even in the oats from this plot, for in spite of their poor development, light weight, and large percentage of fiber, the percentage of protein is as high as in the oats from plot 11, which weighed 29 lbs. to the bushel, and contained 2.25 per cent. less fiber.

The varying amounts of nitrogen supplied in the form of dried blood seem to have had no effect on the composition of the crop, though there was a decided increase in yield per acre upon the different plots.

Pounds of Protein per Acre in Crop.

FERTILIZERS.	OATS.			STRAW.			OATS AND STRAW.		
	Nitrate of Soda Group.	Sulphate of Ammonia Group.	Dried Blood Group.	Nitrate of Soda Group.	Sulphate of Ammonia Group.	Dried Blood Group.	Nitrate of Soda Group.	Sulphate of Ammonia Group.	Dried Blood Group.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Mixed Minerals and 25 lbs. of Nitrogen, - - - - -	68	43	53	43	41	40	111	84	93
Mixed Minerals and 50 lbs. of Nitrogen, - - - - -	82	58	57	58	53	44	140	111	101
Mixed Minerals and 75 lbs. of Nitrogen, - - - - -	100	68	79	78	87	67	178	153	146

The preceding table gives the pounds of protein in the crop from one acre. This table takes into account the increased percentages of protein resulting from the addition of nitrogen in the fertilizers and also the increased yield. The nitrate of soda group shows the most marked increase in pounds of protein per acre. It will be observed that the increase in pounds of protein per acre from the application of different amounts of dried blood was very noticeable, though there was little difference in the percentage composition of the crops from the different plots of that group.

One hundred and sixty-two pounds of protein contain about 25 pounds of nitrogen. In other words, if a plant could assimilate and change 25 lbs. of nitrogen into protein, 162 lbs. would be formed. Hence, the application of 25 lbs. of nitrogen in a fertilizer, if all taken up and transformed by the growing plant, would form 162 lbs. of protein, which should be found in the resulting crop. Assuming that the soil furnished no more nitrogen to the plants than was left behind in roots and stubble, and that no nitrogen was taken from the air, it will be seen that in the crop from the plots to which nitrate of soda was applied, the application of 25 lbs. of nitrogen did not give its full return in protein by 50 lbs. The application of 50 lbs. of nitrogen gave 185 lbs. less protein than it might theoretically have given, and where 75 lbs. of nitrogen were applied there was over 300 lbs. less protein found in the crop than might have been there if all of the nitrogen had been taken up and utilized. The protein of the crop was increased more by the application of nitrate of soda than by that of sulphate of ammonia or dried blood. Hence it follows, that there was a still greater loss of nitrogen in the use of these latter nitrogenous fertilizers.

INCREASE IN YIELD PER ACRE WITH FERTILIZERS.

The figures in the first and second columns of Table 32, which follows, show the increase in yield of oats and of straw as indicated by harvest weights, above the average yield from the unfertilized plots, and the third column contains figures indicating the increase in yield of the total dry matter of oats and straw. The increase in yield from the use of mixed minerals is considerable, but the addition of nitrogen in the fertilizers applied seems to have been necessary to produce a marked increase in yield.

The yield per acre in all three groups increased in proportion to the quantity of nitrogen applied in the fertilizers. The largest increase in yield was from the use of nitrate of soda, and the next largest from the use of dried blood. In speaking of the increase in yield due to fertilizers, it is necessary to assume that the condition of the soil is uniform, which is rarely the case. The last three columns show the increase in pounds per acre of protein, fat, and nitrogen-free extract in the total yield. This increase is mostly in the proportion of the increase in water-free substance per acre, but is influenced somewhat by the differences in percentage composition of the crops from the different plots.

TABLE 32.

SPECIAL NITROGEN EXPERIMENT WITH OATS.

Gain per Acre in Pounds on Fertilized as Compared with Unfertilized Plots.

Plot Number.	FERTILIZERS.	HARVEST WEIGHTS.		IN WATER-FREE SUBSTANCE OF OATS AND STRAW.			
		Oats.	Straw.	Water-free Substance.	Protein.	Fat.	Nitrogen-free Extract.
6*a*	Dis. Bone-blk. Mixed Mur. of Potash Min'rls.	211	320	456	39	20	247
6*b*	Mixed Minerals, as 6*a*, -	291	384	569	50	26	321
	Average Mixed Minerals, -	251	352	513	45	23	284
	Nitrate of Soda Group—						
7	Mixed Minerals, as 6*a*, Nit. Soda, 25 lbs. Nit'gen,	419	808	1041	86	50	559
8	Mixed Minerals, as 6*a*, Nit. Soda, 50 lbs. Nit'gen,	499	1096	1366	115	57	729
9	Mixed Minerals, as 6*a*, Nit. Soda, 75 lbs. Nit'gen,	619	1312	1648	153	73	862
	Sulph. Ammonia Group—						
10	Mixed Minerals, as 6*a*, Sul. Am., 25 lbs. Nit'gen,	259	672	796	59	35	432
11	Mixed Minerals, as 6*a*, Sul. Am., 50 lbs. Nit'gen,	347	712	914	66	40	494
12	Mixed Minerals, as 6*a*, Sul. Am., 75 lbs. Nit'gen,	443	1160	1366	80	53	710
	Dried Blood Group—						
13	Mixed Minerals, as 6*a*, Dr. Blood, 25 lbs. Nit'gen,	339	648	834	68	35	453
14	Mixed Minerals, as 6*a*, Dr. Blood, 50 lbs. Nit'gen,	371	784	1000	76	40	545
15	Mixed Minerals, as 6*a*, Dr. Blood, 75 lbs. Nit'gen,	531	1264	1538	121	62	827

SUMMARY.

The Experiment.

The experiment was similar to the special nitrogen experiments upon corn conducted by the Station, and to the experiment on grasses reported on pages 44–56 of this Report. Mixed minerals (phosphoric acid and potash) were applied to all the plots except three, which were left unmanured. To the manured plots, except two, nitrogen in the form of nitrate of soda, sulphate of ammonia, or dried blood was applied at the rate of 25, 50 and 75 lbs. per acre. The plots contained one-sixteenth of an acre, and were separated by unmanured strips. The soil was considerably reduced in fertility, and does not appear to have been very uniform.

The Results.

The yield per acre was small on the unmanured plots, somewhat larger on the plots to which the mixed minerals were applied alone, and largest on the plots having nitrogenous fertilizers in addition to the mixed minerals. In general the oats were heaviest (i. e., weighed the most per bushel) on the plots of the nitrate of soda group, less on the other fertilized plots, and considerably less on the unmanured plots. There was a uniform relation between the weight per bushel of the oats and the percentage of fiber. The percentage of fiber diminished as the weight per bushel increased.

The percentages of protein (nitrogen × 6.25) increased in both oats and straw, with the application of nitrogen in the form of nitrate of soda or sulphate of ammonia, and this increase was in proportion to the amount applied.

The use of different amounts of dried blood in the fertilizer did not materially affect the percentages of protein in either the oats or the straw.

There was an increase in pounds of protein per acre in the plots supplied with nitrogenous fertilizers somewhat in proportion to the amounts applied. This increase was greatest in the plots to which nitrate of soda was applied. These results are in accord with observations made by the Station upon the relation of the protein in maize, and in grass, to the nitrogen applied in the fertilizer.

The increase in the amount of nitrogen in the crop did not equal the increase in amount of nitrogen applied in the fertilizers, implying that the plants were not able to avail themselves of all the nitrogen supplied.

EFFECTS OF DIFFERENT FERTILIZERS UPON THE COMPOSITION OF CORN.

BY

CHARLES D. WOODS AND H. B. GIBSON.

In 1888 and 1889, in connection with the field experiments with fertilizers, analysis of the produce grown was undertaken, in order to study the effects of different fertilizers upon the percentage composition, and upon the total yield of nutritive ingredients of the grain and stover of the maize plant, with especial reference to the effect of nitrogenous fertilizers upon the amount of protein.

In continuation of the study of maize, samples have been taken and analyzed from two of the "soil test" experiments of 1890; one conducted by Mr. May, and described on pages 68 and 69 of this Report; the other by Mr. Dean, described on pages 63–66. The crop from Mr. May's experiment was analyzed, with a view of ascertaining the errors of field sampling, and is discussed more fully in that connection in a later part of the Report. The yield was quite uniform and heavy on all of the plots, including the unmanured, ranging from 43 to 57 bushels of shelled corn per acre. With so large a yield, it was not expected that marked differences in composition would appear. Two samples were analyzed from each plot. The figures given in Tables 33 and 34 show the averages of the results of the analyses of the two samples from each plot.

The crop from Mr. Dean's experiment was analyzed because of the great difference in yield from the use of different fertilizers obtained in 1889, and the still more marked result of 1890. On page 65 is given a diagram showing the comparative yield of shelled corn per acre. The range is from 4 bushels on one of the unmanured plots to 44 bushels on the plot (E) having nitrate of soda and muriate of potash.

The most striking result of the analysis of the crop in this experiment is the very marked falling off in percentages of protein in both corn and stover of the crop from the last four plots (E, F, G, and G*a*) of the experiment. At first it was thought that there might have been an error in the analytical work, and the analyses were repeated after an interval of nearly a month with the same results as at first. To what this decrease of two per cent. of protein in the corn, and five per cent. in the stover is to be attributed, is not apparent.

TABLE 33.

Soil Test with Maize, by C. E. May. Proximate Composition of Corn and Stover, Calculated on Water-free Substance.

No. of Plot.	FERTILIZERS.	CORN.						STOVER.					
		Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Nitrogen.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Nitrogen.
		%	%	%	%	%	%	%	%	%	%	%	%
0.	Unmanured,	10.43	5.32	81.14	1.53	1.58	1.67	4.35	1.59	50.27	38.30	5.49	.70
00.	Unmanured,	10.47	5.07	81.39	1.49	1.58	1.68	5.59	1.72	50.17	37.34	5.18	.90
	Average of unmanured,	10.45	5.20	81.26	1.51	1.58	1.68	4.97	1.66	50.22	37.82	5.33	.80
A.	Nitrate of Soda,	11.35	5.07	80.67	1.43	1.48	1.82	5.31	2.12	49.63	37.92	5.02	.85
B.	Dis. Bone-black,	10.35	5.18	81.43	1.44	1.60	1.66	4.38	2.23	50.40	37.69	5.30	.70
C.	Muriate of Potash,	10.37	5.10	81.62	1.40	1.51	1.66	4.44	2.06	49.30	38.08	6.12	.71
D.	Nitrate of Soda, Dis. Bone-black,	11.43	5.25	80.33	1.46	1.53	1.83	4.91	2.01	51.34	36.79	4.95	.79
E.	Nitrate of Soda, Muriate of Potash,	10.19	5.05	81.79	1.38	1.59	1.63	4.82	2.05	49.63	37.61	5.89	.77
F.	Dis. Bone-black, Muriate of Potash,	10.22	5.35	81.45	1.36	1.62	1.64	4.04	1.92	50.37	37.60	6.07	.65
G.	Nitrate of Soda, Dis. Bone-black, Muriate of Potash,	11.37	5.32	80.35	1.39	1.57	1.82	4.78	2.13	50.71	36.48	5.90	.77
H.	Plaster,	10.47	5.16	81.51	1.38	1.48	1.68	4.41	2.03	51.15	36.89	5.52	.71
	Minimum,	10.19	5.05	80.34	1.36	1.48	1.63	4.04	1.59	49.30	36.48	4.95	.65
	Maximum,	11.44	5.35	81.79	1.53	1.62	1.83	5.59	2.23	51.34	38.30	6.12	.90
	Average,	**10.67**	**5.19**	**81.17**	**1.42**	**1.55**	**1.71**	**4.70**	**1.98**	**50.30**	**37.47**	**5.55**	**.75**

TABLE 34.

Soil Test with Maize, by C. E. May. Proximate Composition of Corn and Stover, Calculated to Water Content at Harvest.

No. of Plot.	FERTILIZERS.	CORN.						STOVER.					
		Water.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Water.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
		%	%	%	%	%	%	%	%	%	%	%	%
O.	Unmanured,	23.99	7.93	4.04	61.67	1.17	1.20	36.66	2.75	1.01	31.83	24.28	3.47
OO.	Unmanured,	22.63	8.10	3.92	62.97	1.15	1.23	24.54	4.21	1.31	37.84	28.17	3.93
	Average of unmanured,	23.31	8.01	3.98	62.32	1.16	1.22	30.60	3.48	1.16	34.83	26.23	3.70
A.	Nitrate of Soda,	22.87	8.75	3.91	62.23	1.10	1.14	29.79	3.72	1.49	34.85	26.63	3.52
B.	Dis. Bone-black,	23.10	7.96	3.99	62.61	1.11	1.23	37.23	2.75	1.40	31.63	23.66	3.33
C.	Muriate of Potash,	21.91	8.09	3.99	63.74	1.09	1.18	33.27	2.96	1.36	32.91	25.43	4.07
D.	Nitrate of Soda, Dis. Bone-black,	22.36	8.88	4.08	62.36	1.13	1.19	35.00	3.20	1.31	33.35	23.92	3.22
E.	Nitrate of Soda, Muriate of Potash,	21.03	8.04	3.99	64.59	1.09	1.26	38.75	2.95	1.26	30.39	23.04	3.61
F.	Dis. Bone-black, Muriate of Potash,	23.64	7.80	4.09	62.19	1.04	1.24	39.23	2.45	1.17	30.61	22.85	3.69
G.	Nitrate of Soda, Dis. Bone-black, Muriate of Potash,	23.48	8.70	4.07	61.48	1.06	1.21	43.19	2.72	1.21	28.80	20.73	3.35
H.	Plaster,	21.14	8.26	4.07	64.28	1.08	1.17	27.11	3.21	1.48	37.29	26.89	4.02
	Minimum,	21.03	7.80	3.91	61.48	1.04	1.14	24.54	2.45	1.01	28.80	20.73	3.22
	Maximum,	23.99	8.88	4.09	64.59	1.17	1.26	43.19	4.21	1.49	37.84	28.17	4.07
	Average,	**22.62**	**8.25**	**4.01**	**62.81**	**1.10**	**1.21**	**34.48**	**3.09**	**1.30**	**32.95**	**24.56**	**3.62**

TABLE 35.

Soil Test with Maize, by M. H. Dean. Proximate Composition of Corn and Stover, Calculated on Water-free Substance.

No. of Plot.	FERTILIZERS.	CORN.							STOVER.						
		Laboratory No.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Nitrogen.	Laboratory No.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Nitrogen.
			%	%	%	%	%	%		%	%	%	%	%	%
o.	Unmanured, - - -	913	12.38	4.84	78.72	2.14	1.92	1.98	912	10.00	1.83	52.19	31.21	4.77	1.60
oo.	Unmanured, - - -	917	11.13	4.84	80.29	1.96	1.78	1.78	916	8.88	1.66	52.05	32.42	4.99	1.42
	Average of unmanured, -	—	11.76	4.84	79.50	2.05	1.85	1.88	—	9.44	1.75	52.12	31.81	4.88	1.51
A.	Nitrate of Soda, - -	921	11.81	5.06	79.91	1.58	1.64	1.89	920	9.63	1.62	51.59	32.14	5.02	1.54
B.	Dissolved Bone-black, -	925	10.94	4.73	80.78	1.86	1.69	1.75	924	10.06	1.55	50.47	32.42	5.50	1.61
C.	Muriate of Potash, - -	929	8.44	5.01	83.23	1.89	1.43	1.35	928	8.56	3.12	50.04	32.88	5.40	1.37
D.	Nitrate of Soda, - Dissolved Bone-black,	933	11.31	5.05	80.21	1.81	1.62	1.81	932	9.06	1.53	50.78	33.91	4.72	1.45
E.	Nitrate of Soda, - Muriate of Potash, -	937	9.00	5.11	82.80	1.65	1.44	1.44	936	5.75	2.09	52.04	34.80	5.32	.92
F.	Dissolved Bone-black, Muriate of Potash, -	941	8.25	5.26	83.24	1.72	1.53	1.32	940	4.25	2.67	55.20	32.78	5.10	.68
G.	Nitrate of Soda, - Dissolved Bone-black, Muriate of Potash, -	945	9.06	5.39	82.50	1.55	1.44	1.45	944	5.13	1.89	51.79	35.33	5.86	.82
Ga.	Nitrate of Soda, - Dissolved Bone-black, Muriate of Potash, -	949	8.69	5.04	83.28	1.48	1.51	1.39	948	4.74	1.85	51.81	35.63	5.97	.79
	Minimum, - - - -	—	8.25	4.73	78.72	1.48	1.43	1.32	—	4.25	1.55	50.04	31.21	4.72	.68
	Maximum, - - - -	—	12.38	5.39	83.28	2.14	1.92	1.98	—	10.06	3.12	55.20	35.63	5.97	1.61
	Average, - - - -	—	**10.10**	**5.03**	**81.51**	**.76**	**1.60**	**1.62**	—	**7.61**	**1.98**	**51.79**	**33.35**	**5.27**	**1.22**

TABLE 36.

Soil Test with Maize, by M. H. Dean. Proximate Composition of Corn and Stover, Calculated to Water Content at Time of Harvest.

No. of Plot.	FERTILIZERS.	CORN.							STOVER.						
		Laboratory No.	Water.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Laboratory No.	Water.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			%	%	%	%	%	%		%	%	%	%	%	%
O.	Unmanured, - - - -	913	29.44	8.74	3.42	55.54	1.51	1.35	912	50.09	4.99	.91	26.05	15.58	2.38
OO.	Unmanured, - - - -	917	31.29	7.65	3.33	55.16	1.35	1.22	916	45.15	4.87	.91	28.55	17.78	2.74
	Average of unmanured, -	—	30.36	8.19	3.38	55.35	1.43	1.29	—	47.62	4.93	.91	27.30	16.68	2.56
A.	Nitrate of Soda, - -	921	27.94	8.51	3.65	57.58	1.14	1.18	920	41.68	5.62	.94	30.09	18.74	2.93
B.	Dissolved Bone-black, -	925	29.56	7.71	3.31	56.90	1.31	1.19	924	55.49	4.48	.69	22.46	14.43	2.45
C.	Muriate of Potash, - -	929	29.17	5.98	3.55	58.95	1.34	1.01	928	65.38	2.96	1.08	17.33	11.38	1.87
D.	Nitrate of Soda, - Dissolved Bone-black,	933	28.35	8.10	3.62	57.47	1.30	1.16	932	45.18	4.97	.84	27.83	18.59	2.59
E.	Nitrate of Soda, - Muriate of Potash, -	937	27.11	6.56	3.72	60.36	1.20	1.05	936	56.33	2.51	.91	22.73	15.20	2.32
F.	Dissolved Bone-black, Muriate of Potash, -	941	27.23	6.00	3.83	60.58	1.25	1.11	940	56.08	1.87	1.17	24.24	14.40	2.24
G.	Nitrate of Soda, - Dissolved Bone-black, Muriate of Potash, -	945	26.22	6.68	3.98	60.92	1.44	1.06	944	52.56	2.43	.90	24.57	16.76	2.78
G*a*.	Nitrate of Soda, - Dissolved Bone-black, Muriate of Potash, -	949	27.46	6.30	3.66	60.39	1.09	1.10	948	63.21	1.74	.68	19.06	13.11	2.20
	Minimum, - - - - -	—	27.11	5.98	3.31	55.16	1.09	1.01	—	41.68	1.74	.68	17.33	11.38	1.87
	Maximum, - - - - -	—	31.29	8.74	3.98	60.92	1.51	1.35	—	65.38	5.62	1.17	30.09	18.74	2.93
	Average, - - - - -	—	**28.37**	**7.22**	**3.60**	**58.38**	**1.29**	**1.14**	—	**53.11**	**3.65**	**.90**	**24.29**	**15.60**	**2.45**

PROXIMATE COMPOSITION OF CORN AND STOVER OF NEW ENGLAND GROWN MAIZE.

BY

CHAS. D. WOODS AND H. B. GIBSON.

In connection with the study of the composition of crops grown in field experiments with fertilizers during the past three years, there have been made 121 analyses of grain of yellow flint and 10 of that of white flint corn, and 101 analyses of stover of yellow flint and 10 of that of white flint corn.

The analyses were all made by the same methods (those adopted by the Association of Official Agricultural Chemists), and by the same analysts, yet the extremes in percentage composition are wide. During the season of 1889 the seed used in the field experiments with maize was supplied by the Station and was all alike. The extremes in composition were as wide that season as in either of the other two in which the experimenters furnished the seed. Indeed, the variations in percentage composition were nearly as great in the crop from the different plots of one experiment of 1889 as in the whole range of samples analyzed.

COMPOSITION OF CORN.

Table 37, which follows, gives the minimum, maximum, and average composition of the grain of yellow flint corn from the plots supplied with different fertilizers. A few of the samples taken for analysis consisted of selected kernels of perfect corn, but for the most part both sound and immature corn were included in the samples in about the same proportions in which they occurred in the crops from the different plots. The first column shows the kind of fertilizer that was applied; the second, the number of analyses from the results of which the percentage composition given in the other columns are derived.

The tendency of a complete fertilizer to produce corn richer in protein and fats is somewhat noticeable. Taking the average of the samples of corn containing both perfect and immature kernels, there is not as marked an increase in percentage of protein in accordance with the amount of nitrogen supplied in the fertilizer as was observed in the perfect kernels analyzed in

1888.* Still, the addition of nitrogen produced a corn richer in protein than was obtained from the use of mineral fertilizers alone.

TABLE 37.

Composition of Yellow Flint Corn from Plots Supplied with Different Fertilizers.

FERTILIZERS.	No. of Analyses.	Water at Harvest.	IN WATER-FREE SUBSTANCE.				
			Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
		%	%	%	%	%	%
Unmanured.							
Minimum,	13	22.28[1]	10.19	4.84	78.25	1.46	1.53
Maximum,	13	31.39[1]	12.50	6.01	81.85	2.25	2.05
Average,	13	**26.04[1]**	**11.28**	**5.26**	**79.98**	**1.75**	**1.73**
Nitrate of Soda.							
Minimum,	8	22.55[2]	10.63	5.04	78.09	1.38	1.45
Maximum,	8	30.80[2]	12.75	6.00	80.85	2.27	2.05
Average,	8	**25.43[2]**	**11.75**	**5.31**	**79.53**	**1.72**	**1.69**
Dissolved Bone-black.							
Minimum,	9	22.04[3]	10.31	4.73	77.38	1.41	1.53
Maximum,	9	29.56[3]	13.25	5.58	81.59	2.08	2.01
Average,	9	**26.17[3]**	**11.16**	**5.23**	**80.14**	**1.73**	**1.74**
Muriate of Potash.							
Minimum,	9	21.13[3]	8.44	4.93	80.07	1.39	1.43
Maximum,	9	29.75[3]	11.19	5.65	83.23	2.06	1.89
Average,	9	**25.92[3]**	**10.20**	**5.21**	**81.26**	**1.68**	**1.65**
Nitrate of Soda.							
Dissolved Bone-black.							
Minimum,	8	22.22[3]	11.31	4.99	77.12	1.44	1.52
Maximum,	8	28.93[3]	12.44	6.87	80.40	1.91	1.99
Average,	8	**24.91[3]**	**11.81**	**5.52**	**79.32**	**1.62**	**1.73**
Nitrate of Soda.							
Muriate of Potash,							
Minimum,	8	20.42[2]	9.00	5.04	78.43	1.35	1.44
Maximum,	8	27.96[2]	12.94	6.26	82.80	2.00	2.12
Average,	8	**24.00[2]**	**10.86**	**5.40**	**80.40**	**1.60**	**1.74**
Mur. of Potash, } *Mixed*							
Dis. Bone-black, } *Minerals.*							
Minimum,	10	23.58[3]	8.25	4.73	77.95	1.33	1.53
Maximum,	10	30.06[3]	11.44	6.78	83.24	2.22	2.17
Average,	10	**25.92[3]**	**10.33**	**5.55**	**80.74**	**1.66**	**1.72**
Mixed Minerals.							
25 lbs. Nitrogen as Nitrate of Soda.							
Minimum,	7	23.11[3]	9.06	5.04	78.23	1.33	1.44
Maximum,	7	27.26[3]	11.69	7.22	80.51	2.05	2.06
Average,	7	**25.07[3]**	**10.78**	**5.62**	**80.22**	**1.69**	**1.69**

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* Report of this Station, 1889, pp. 161 and 162.

TABLE 37.—*(Continued.)*

FERTILIZERS.	No. of Analyses.	Water at Harvest.	IN WATER-FREE SUBSTANCE.				
			Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
		%	%	%	%	%	%
Mixed Minerals. 25 lbs. Nitrogen from various sources.							
Minimum, - - -	14	23.11[4]	9.00	5.04	77.90	1.33	1.44
Maximum, - - -	14	29.72[4]	12.69	7.22	81.29	2.41	2.06
Average, - - -	14	**26.29**[4]	**10.73**	**5.80**	**79.96**	**1.76**	**1.75**
Mixed Minerals. 50 lbs. Nitrogen from various sources.							
Minimum, - - -	9	27.43[3]	8.94	4.99	77.60	1.50	1.58
Maximum, - - -	9	28.89[3]	12.19	7.12	81.94	2.27	2.07
Average, - - -	9	**28.04**[3]	**10.71**	**5.91**	**79.79**	**1.83**	**1.76**
Mixed Minerals. 75 lbs. Nitrogen from various sources.							
Minimum, - - -	9	26.92[3]	9.19	5.10	77.93	1.52	1.60
Maximum, - - -	9	28.98[3]	13.19	7.03	80.98	2.24	2.28
Average, - - -	9	**28.09**[3]	**11.13**	**5.98**	**79.17**	**1.85**	**1.87**

1, 9 analyses. 2, 5 analyses. 3, 6 analyses. 4, 10 analyses.

Table 38 shows the composition of grain of yellow flint corn without regard to kinds of fertilizer used in the experiments. The corn is grouped in accordance with its condition or state of development when samples were taken for analysis. The first group of perfect kernels gives the results of 44 analyses of selected kernels of corn taken from the field experiments of 1888. They contain a relatively large number of samples from plots supplied with nitrogenous fertilizers.

The samples of "poor" corn, consisting of soft ears and "nubbins," were taken from the whole field in the experiments, and were selected without reference to fertilizers applied. As the yield of "poor" corn per acre was usually largest on the unmanured plots, doubtless much of this corn came from these plots. The details of the analyses are given on pages 26–29 of this Report.

In the 68 analyses designated as "whole crop," the samples consisted of ripe and immature corn in about the same proportion as was found in the crops from the different plots. As these samples were mostly taken from "soil test experiments," the number of plots having nitrogenous fertilizers was small.

The minimum, maximum, and average of all the samples of corn show a wide range in composition. The water at time of harvest, as found in 68 analyses, varies from 20 to 30 per cent., with an average of 26 per cent. The variations in protein of 5, in fat of 3, and in nitrogen-free extract of 6 per cent., show that the water-free substance of corn grown upon different soils, with different fertilizers, in different seasons, varies greatly in composition and in feeding value.

TABLE 38.

Composition of Yellow Flint Corn Grown with Use of Various Fertilizers.

	No. of Analyses.	Water at Harvest.	In Water-free Substance.				
			Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
Perfect Kernels.		%	%	%	%	%	%
Minimum, - - -	44	—	9.88	4.87	77.64	1.23	1.19
Maximum, - - -	44	—	13.25	6.94	81.66	1.81	2.13
Average, - - -	44	—	**11.42**	**5.44**	**79.92**	**1.58**	**1.64**
Poor Corn, Soft Ears and Nubbins.							
Minimum, - - -	9	—	11.63	4.25	76.95	1.53	1.43
Maximum, - - -	9	—	13.38	6.46	80.77	1.86	2.43
Average, - - -	9	—	**12.50**	**4.97**	**79.14**	**1.68**	**1.71**
Whole Crop.							
Minimum, - - -	68	20.42	8.25	4.43	77.12	1.33	1.43
Maximum, - - -	68	30.80	13.25	7.22	83.28	2.41	2.28
Average, - - -	68	**25.96**	**10.66**	**5.52**	**80.28**	**1.78**	**1.76**
Minimum of above, -	121	20.42*	8.25	4.43	76.95	1.23	1.19
Maximum of above, -	121	30.80*	13.38	7.22	83.28	2.41	2.43
Average of above, -	121	**25.96***	**11.08**	**5.45**	**80.06**	**1.70**	**1.71**

Table 39, which follows, gives the composition of perfect kernels of corn, as found in 10 samples of white flint corn.

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* Sixty-eight samples.

TABLE 39.

Composition of White Flint Corn Grown with Use of Various Fertilizers.

	No. of Analyses.	In Water-free Substance.				
		Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
Perfect Kernels.		%	%	%	%	%
Minimum, - - - - -	10	12.44	5.23	76.89	1.37	1.50
Maximum, - - - - -	10	14.38	6.34	78.88	1.66	1.72
Average, - - - - -	10	**13.18**	**5.64**	**78.09**	**1.48**	**1.61**

COMPOSITION OF STOVER.

Table 40, which follows, contains the minimum, maximum, and average composition of the stover of yellow flint corn from the plots supplied with different fertilizers. The great range in composition doubtless depends more upon the difficulty of getting samples fairly representing the yield on the different plots and upon the amount of seed developed, than upon the fertilizers applied.

Table 41 gives the minimum, maximum, and average composition of stover of yellow flint corn as found by analyses of 101 samples taken from unmanured plots and from those treated with various kinds and quantities of fertilizers, and the results of the analyses of 10 samples of stover of white flint corn grown on different plots with different treatment.

The variations in percentages of water at harvest and in the composition of the water-free substance of stover, are much more marked than those of corn. There is an extreme variation of more than fifty per cent. in the water at harvest and of seven per cent. in the protein. In some cases the percentage of protein in stover equals that of average corn and exceeds that of some of the corn by nearly two per cent. The great range indicates the great differences that may be expected in the feeding values of stover from different fields, or even from different parts of the same field when fertilized differently.

TABLE 40.

Composition of Stover of Yellow Flint Corn from Plots Supplied with Different Fertilizers.

FERTILIZERS.	No. of Analyses.	Water at Harvest.	IN WATER-FREE SUBSTANCE.				
			Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
		%	%	%	%	%	%
Unmanured.							
Minimum, - - -	13	19.39	4.06	1.52	48.25	30.74	4.77
Maximum, - - -	13	62.08	10.00	2.44	52.37	39.16	7.16
Average, - - -	13	**41.98**	**6.88**	**1.81**	**50.75**	**34.85**	**5.71**
Nitrate of Soda.							
Minimum, - - -	8	27.32	5.06	1.62	49.50	29.69	4.40
Maximum, - - -	8	53.29	9.63	2.16	54.59	38.26	5.63
Average, - - -	8	**41.70**	**7.49**	**1.91**	**51.17**	**34.25**	**5.18**
Dissolved Bone-black.							
Minimum, - - -	9	32.38	4.06	1.55	49.75	30.73	4.90
Maximum, - - -	9	59.26	10.06	2.57	53.10	38.10	6.59
Average, - - -	9	**44.20**	**6.77**	**2.00**	**51.41**	**34.14**	**5.68**
Muriate of Potash.							
Minimum, - - -	9	29.29	4.13	1.78	48.98	29.97	5.40
Maximum, - - -	9	65.38	8.56	3.12	56.99	38.63	7.85
Average, - - -	9	**49.07**	**5.98**	**2.14**	**51.63**	**34.04**	**6.21**
Nitrate of Soda. *Dissolved Bone-black.*							
Minimum, - - -	8	33.89	4.88	1.53	49.90	30.25	4.67
Maximum, - - -	8	57.68	9.31	2.10	53.57	36.84	6.60
Average, - - -	8	**43.47**	**7.34**	**1.87**	**51.39**	**34.03**	**5.38**
Nitrate of Soda. *Muriate of Potash.*							
Minimum, - - -	8	36.72	4.75	1.73	49.63	31.86	5.32
Maximum, - - -	8	62.81	8.75	2.20	52.51	37.72	7.41
Average, - - -	8	**48.34**	**6.39**	**1.97**	**50.74**	**34.86**	**6.04**
Mur. of Potash, } *Mixed* *Dis. Bone-black,* } *Minerals.*							
Minimum, - - -	10	37.68	3.88	1.61	48.56	31.13	5.10
Maximum, - - -	10	60.37	7.06	2.67	56.66	37.82	7.55
Average, - - -	10	**50.48**	**5.22**	**2.10**	**52.24**	**34.14**	**6.30**
Mixed Minerals. *25 lbs. Nitrogen as Nitrate of Soda.*							
Minimum, - - -	7	39.50	4.75	1.55	49.62	33.74	5.35
Maximum, - - -	7	52.96	8.69	2.21	54.04	36.24	6.94
Average, - - -	7	**45.01**	**5.41**	**1.89**	**51.67**	**35.21**	**5.82**
Mixed Minerals. *25 lbs. Nitrogen from various sources.*							
Minimum, - - -	14	39.50	4.56	1.55	46.73	32.14	5.35
Maximum, - - -	14	64.40	8.69	2.21	54.74	36.24	7.58
Average, - - -	14	**49.89**	**5.67**	**1.89**	**51.98**	**34.38**	**6.08**

TABLE 40.—*(Continued.)*

FERTILIZERS.	No. of Analyses.	Water at Harvest.	IN WATER-FREE SUBSTANCE.				
			Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
		%	%	%	%	%	%
Mixed Minerals.							
50 lbs. Nitrogen from various sources.							
Minimum, - - -	9	40.09	4.06	1.38	48.33	33.09	5.42
Maximum, - - -	9	61.95	7.94	1.97	53.60	36.85	6.95
Average, - - -	9	**52.16**	**5.45**	**1.82**	**52.08**	**34.75**	**5.90**
Mixed Minerals.							
75 lbs. Nitrogen from various sources.							
Minimum, - - -	9	30.37	4.38	1.32	45.87	32.83	5.22
Maximum, - - -	9	63.91	7.53	2.10	53.82	36.50	9.53
Average, - - -	9	**50.49**	**6.12**	**1.80**	**51.06**	**34.79**	**6.23**

TABLE 41.

Composition of Stover of Maize Grown with Use of Various Fertilizers.

FERTILIZERS.	No. of Analyses.	Water at Harvest.	IN WATER-FREE SUBSTANCE.				
			Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
		%	%	%	%	%	%
Yellow Flint.							
Minimum, - - -	101	19.39	3.88	1.32	45.87	29.69	4.40
Maximum, - - -	101	65.38	10.06	3.12	56.99	39.16	9.53
Average, - - -	101	**47.13**	**6.23**	**1.93**	**51.47**	**34.49**	**5.88**
White Flint.							
Minimum, - - -	10	60.79	8.06	1.96	46.90	30.95	6.40
Maximum, - - -	10	71.36	11.31	2.57	49.89	33.48	8.88
Average, - - -	10	**66.33**	**9.51**	**2.18**	**48.35**	**32.26**	**7.70**

SUMMARY.

Percentages of Water at Harvest and Composition of Water-free Substance of New England-grown Maize, Corn and Stover.

	No. of Analyses.	Water at Harvest.	In Water-free Substance.				
			Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
		%	%	%	%	%	%
Corn (Grain).							
Yellow Flint:							
Perfect kernels, - -	44	—	11.42	5.44	79.92	1.58	1.64
Soft ears and nubbins, -	9	—	12.50	4.97	79.14	1.68	1.71
Whole crop, - - -	68	25.96	10.66	5.52	80.28	1.78	1.76
White Flint Corn:							
Perfect kernels, - -	10	—	13.18	5.64	78.09	1.48	1.61
Flint, compiled,* - -	36	—	12.43	5.59	78.80	1.56	1.62
Average of all, - -	167	—	**11.49**	**5.49**	**79.67**	**1.66**	**1.69**
Stover.							
Yellow Flint, - - -	101	47.13	6.23	1.93	51.47	34.49	5.88
White Flint, - - -	10	66.33	9.51	2.18	48.35	32.26	7.70
Average of all, - -	111	**48.86**	**6.52**	**1.95**	**51.20**	**34.29**	**6.04**

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* Report of Conn. Station, 1888, p. 92.

Composition of New England-grown Maize, Corn and Stover. Averages of all Analyses calculated to Uniform Water Basis.

	No. of Analyses.	Water.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
		%	%	%	%	%	%
Corn (Grain).							
With 11 % of water, - -	167	11.00	10.23	4.89	70.90	1.48	1.50
With 26 % of water, - -	167	26.00	8.50	4.06	58.96	1.23	1.25
Stover.							
With 11 % of water, - -	111	11.00	5.80	1.74	45.57	30.52	5.37
With 49 % of water, - -	111	49.00	3.33	.99	26.11	17.49	3.08

ON SOURCES OF ERROR IN FIELD SAMPLING OF CROPS FOR ANALYSIS.

BY

CHAS. D. WOODS.

In the analyses of the samples from the field experiments of 1888 and 1889 some unexpected differences of composition were noted, and the question naturally arose as to whether these differences were due to actual differences in composition of the crop from different plots, or whether it might be in part due to errors of sampling. To test this, during the season of 1890 duplicate samples were analyzed from each plot of one soil test experiment with maize, and triplicate samples from each plot of a special nitrogen experiment with grass. The results of the analyses are given in the tables and discussions which follow. All the determinations were made in duplicate, and in case of unexpected differences between average results of different samples, the results were verified by a third determination.

The samples were taken by the Agriculturist, and Assistant Chemist. The larger part of the analytical work was performed by the Assistant Chemist.

METHODS OF OBTAINING THE SAMPLES.

In the Field.

Maize.—At time of cutting, the maize was put up in small stooks, the yield from 25 or 30 hills being stacked together in one stook. The maize stood in these stooks till time of harvesting. The day selected for harvesting and selecting samples was bright and clear, and the preceding had been a good drying day. The weighing and sampling began about 9 A. M., at which time the dew had dried off. A representative bunch of four to eight plants was taken from every alternate stook and put into a pile. Effort was made to take about half of each sample from the exterior and half from the interior of the stook. The total sample thus obtained made a good-sized armful, varying in weight from ten to fifteen pounds. Three distinct samples were taken in this way from each plot.

Each entire sample was weighed, and husked. The total corn was weighed, and the weight of stover estimated by difference. The stalks from each separate sample were cut into about one inch lengths, and the whole, or very nearly the whole, taken for the laboratory sample. One-half to two-thirds of the ears, selected so as to represent the whole as fairly as possible, were taken for the final sample.

The final samples were weighed, placed in cotton bags and immediately shipped to the laboratory. On receipt at the laboratory they were again weighed, thereby checking the field weights, and the samples of corn were shelled and the proportion of corn and cob ascertained. The field weighings were made to ounces; the laboratory weighings to grams. The loss of moisture in transit was within the error of the field weighings, *i. e.*, less than 28 grams. The samples were dried over a register for a few days until they were dry enough to prevent danger of molding. They were then stored in the laboratory until analyzed. At the time of the analysis the samples were much dryer than they would have been if taken directly from the corn-bin or stover-loft. The different samples from each plot were taken by the same person.

Hay.—When the hay was thought to be dry enough to put into the barn, it was raked into windrows extending crosswise of the plots. They varied in number from four or five on the unmanured plots, to fifteen or twenty on the plots having the heaviest yield. Representative handfuls were taken from each windrow, the number from each diminishing as the number of windrows increased. The total sample weighed from twelve to fifteen pounds, being about all that could be crowded into a bran sack. Three distinct samples were taken in this way from each plot. These large samples were cut into short lengths, and a final sample of about four pounds was selected from each, weighed, and put in a cotton bag for shipment to the laboratory. On receipt at laboratory, the sample was again weighed and then dried over a register for a few days.

Legumes.—Several samples of legumes were taken by selecting for each an area of four square feet, the crop upon which seemed to fairly represent the average of the crop in the different parts of the plot or field, and cutting and taking the total yield of the four square feet for a sample.

Laboratory Preparation for Analysis.

Maize.—The sample of stover was weighed, and then cut into as short pieces as possible by means of a vertical hay-cutter, and carefully sampled. A sample of three to four quarts was ground, being put through the mill once. This was again carefully sampled, and enough to fill an eight-ounce bottle was taken and ground till it would pass through a round hole one millimeter in diameter.

The corn had been shelled, and proportions of corn and cob obtained at time of receipt from the field. In the preparation for analysis, the corn and cobs were again weighed. The corn was carefully sampled and about a pint was ground, being put through the mill once. This was again sampled and treated in the same way as the stover above, except that the final sample filled a four-ounce instead of an eight-ounce bottle.

Hay and Legumes.—The hay was prepared for analysis in the same way as stover. The entire sample of the legumes was ground, being put through the mill once. This was again sampled and ground till it would pass through a round hole one millimeter in diameter.

VARIATIONS IN COMPOSITION OF DIFFERENT SAMPLES FROM SAME PLOTS.

The three following tables (42, 43, and 44) give the results of the analyses of the different samples taken from the same plots at the same time by the same persons. The different samples from these plots are designated as A, B, and C, and the results of the analyses of these samples are given in the first three columns. The next column contains the average of these results, and the remaining columns the variation in percentage composition. Since nitrogen-free extract is not directly determined, it is omitted. The percentage of protein is found by multiplying the percentage of nitrogen by 6.25, hence it follows that a difference of .16 per cent. of nitrogen means a difference of 1 per cent. of protein.

TABLE 42.

Variations in Composition of Samples of Maize (Grain). Percentages of Water at Harvest, and of Nitrogen, Fat, Fiber, and Ash in Water-free Substance of Duplicate Samples, and the Extreme and Mean Variations in Percentages.

Plot No.	Fertilizers.		SAMPLES.			VARIATIONS.	
			A.	B.	Average.	Extreme.	Mean.
			%	%	%	%	%
O.	Unmanured.	*At Harvest.*					
		Water, - - - -	23.19	24.79	23.99	1.60	.80
		In Water-free Substance.					
		Nitrogen, - - - -	1.69	1.65	1.67	.04	.02
		Fat, - - - -	5.50	5.13	5.32	.37	.16
		Fiber, - - - -	1.52	1.54	1.53	.02	.01
		Ash, - - - -	1.53	1.63	1.58	.10	.05
OO.	Unmanured.	*At Harvest.*					
		Water, - - - -	22.28	22.99	22.63	.71	.36
		In Water-free Substance.					
		Nitrogen, - - - -	1.72	1.63	1.68	.09	.05
		Fat, - - - -	5.22	4.91	5.07	.31	.16
		Fiber, - - - -	1.46	1.52	1.49	.06	.03
		Ash, - - - -	1.63	1.53	1.58	.10	.05
A.	Nit. of Soda.	*At Harvest.*					
		Water, - - - -	23.20	22.55	22.87	.65	.33
		In Water-free Substance.					
		Nitrogen, - - - -	1.93	1.70	1.82	.23	.12
		Fat, - - - -	5.09	5.04	5.07	.05	.03
		Fiber, - - - -	1.38	1.48	1.43	.10	.05
		Ash, - - - -	1.45	1.50	1.48	.05	.03
B.	Dis. Bone-black.	*At Harvest.*					
		Water, - - - -	22.04	24.17	23.10	2.13	1.07
		In Water-free Substance.					
		Nitrogen, - - - -	1.65	1.66	1.66	.01	.00
		Fat, - - - -	5.28	5.08	5.18	.20	.10
		Fiber, - - - -	1.46	1.42	1.44	.04	.02
		Ash, - - - -	1.67	1.53	1.60	.14	.07
C.	Mur. of Potash.	*At Harvest.*					
		Water, - - - -	22.70	21.13	21.91	1.57	.79
		In Water-free Substance.					
		Nitrogen, - - - -	1.79	1.53	1.66	.26	.13
		Fat, - - - -	5.19	5.00	5.10	.19	.10
		Fiber, - - - -	1.39	1.40	1.40	.01	.00
		Ash, - - - -	1.50	1.52	1.51	.02	.01

TABLE 42.—*(Continued.)*

Plot No.	Fertilizers.		SAMPLES.			VARIATIONS.	
			A.	B.	Average.	Extreme.	Mean.
			%	%	%	%	%
D.	Nitrate of Soda. Dis. Bone-black.	*At Harvest.*					
		Water, - - -	22.22	22.51	22.36	.29	.15
		In Water-free Substance.					
		Nitrogen, - - -	1.81	1.85	1.83	.04	.02
		Fat, - - - -	5.33	5.17	5.25	.16	.08
		Fiber, - - -	1.44	1.47	1.46	.03	.02
		Ash, - - - -	1.52	1.54	1.53	.02	.01
E.	Nitrate of Soda. Mur. of Potash.	*At Harvest.*					
		Water, - - -	20.42	21.65	21.03	1.23	.62
		In Water-free Substance.					
		Nitrogen, - - -	1.63	1.63	1.63	.00	.00
		Fat, - - - -	5.04	5.06	5.05	.02	.01
		Fiber, - - -	1.37	1.38	1.38	.01	.00
		Ash, - - - -	1.66	1.53	1.59	.13	.07
F.	Dis. Bone-black. Mur. of Potash.	*At Harvest.*					
		Water, - - -	23.71	23.58	23.64	.13	.07
		In Water-free Substance.					
		Nitrogen, - - -	1.66	1.61	1.64	.05	.03
		Fat, - - - -	5.29	5.41	5.35	.12	.06
		Fiber, - - -	1.33	1.39	1.36	.06	.03
		Ash, - - - -	1.61	1.62	1.62	.01	.00
G.	Nitrate of Soda. Dis. Bone-black. Mur. of Potash.	*At Harvest.*					
		Water, - - -	23.29	23.68	23.48	.39	.20
		In Water-free Substance.					
		Nitrogen, - - -	1.84	1.80	1.82	.04	.02
		Fat, - - - -	5.32	5.31	5.32	.01	.00
		Fiber, - - -	1.33	1.44	1.39	.11	.06
		Ash, - - - -	1.60	1.54	1.57	.06	.03
H.	Plaster.	*At Harvest.*					
		Water, - - -	21.15	21.13	21.14	.02	.01
		In Water-free Substance.					
		Nitrogen, - - -	1.71	1.64	1.68	.07	.04
		Fat, - - - -	5.11	5.22	5.16	.11	.06
		Fiber, - - -	1.36	1.39	1.38	.03	.02
		Ash, - - - -	1.44	1.51	1.48	.07	.04

TABLE 43.

Variations in Composition of Samples of Maize Stover. Percentages of Water at Harvest, and of Nitrogen, Fat, Fiber, and Ash in Water-free Substance of Duplicate Samples, and the Extreme and Mean Variations in Percentages.

Plot No.	Fertilizers.		SAMPLES.			VARIATIONS.	
			A.	B.	Average.	Extreme.	Mean.
			%	%	%	%	%
O.	Unmanured.	*At Harvest.*					
		Water, - - - -	33.60	39.72	36.66	6.12	3.06
		In Water-free Substance.					
		Nitrogen, - - -	.65	.74	.70	.09	.05
		Fat, - - - -	1.52	1.66	1.59	.14	.07
		Fiber, - - -	39.16	37.43	38.30	1.73	.87
		Ash, - - - -	5.20	5.79	5.49	.59	.30
OO.	Unmanured.	*At Harvest.*					
		Water, - - - -	29.69	19.39	24.54	10.30	5.15
		In Water-free Substance.					
		Nitrogen, - - -	.92	.87	.90	.05	.03
		Fat, - - - -	1.66	1.78	1.72	.12	.06
		Fiber, - - -	37.49	37.20	37.34	.30	.15
		Ash, - - - -	4.77	5.59	5.18	.82	.41
A.	Nitrate of Soda.	*At Harvest.*					
		Water, - - - -	27.32	32.26	29.79	4.94	2.47
		In Water-free Substance.					
		Nitrogen, - - -	.81	.89	.85	.08	.04
		Fat, - - - -	2.08	2.16	2.12	.08	.04
		Fiber, - - -	38.26	37.58	37.92	.68	.34
		Ash, - - - -	4.83	5.20	5.02	.37	.19
B.	Dis. Bone-black.	*At Harvest.*					
		Water, - - - -	37.03	37.44	37.23	.41	.22
		In Water-free Substance.					
		Nitrogen, - - -	.75	.65	.70	.10	.05
		Fat, - - - -	2.57	1.88	2.23	.69	.35
		Fiber, - - -	37.29	38.10	37.69	.81	.41
		Ash, - - - -	5.70	4.90	5.30	.80	.40
C.	Mur. of Potash.	*At Harvest.*					
		Water, - - - -	37.25	29.29	33.27	7.96	3.98
		In Water-free Substance.					
		Nitrogen, - - -	.76	.66	.71	.10	.05
		Fat, - - - -	2.33	1.78	2.06	.55	.28
		Fiber, - - -	37.54	38.63	38.08	1.09	.55
		Ash, - - - -	6.40	5.84	6.12	.56	.28

TABLE 43.—*(Continued.)*

Plot No.	Fertilizers.		Samples.			Variations.	
			A.	B.	Average.	Extreme.	Mean.
			%	%	%	%	%
D.	Nitrate of Soda. Dis. Bone-black.	*At Harvest.*					
		Water,	33.89	36.11	35.00	2.22	1.11
		In Water-free Substance.					
		Nitrogen,	.78	.79	.79	.01	.00
		Fat,	1.93	2.09	2.01	.16	.08
		Fiber,	36.75	36.84	36.79	.09	.05
		Ash,	5.25	4.67	4.95	.58	.29
E.	Nitrate of Soda. Mur. of Potash.	*At Harvest.*					
		Water,	36.72	40.77	38.75	4.05	2.03
		In Water-free Substance.					
		Nitrogen,	.76	.78	.77	.02	.01
		Fat,	2.20	1.89	2.05	.31	.16
		Fiber,	37.72	37.51	37.61	.21	.11
		Ash,	5.84	5.94	5.89	.10	.05
F.	Dis. Bone-black. Mur. of Potash.	*At Harvest.*					
		Water,	40.78	37.68	39.23	3.10	1.55
		In Water-free Substance.					
		Nitrogen,	.67	.62	.65	.05	.03
		Fat,	2.02	1.82	1.92	.20	.10
		Fiber,	37.38	37.82	37.60	.44	.22
		Ash,	6.28	5.87	6.07	.41	.21
G.	Nitrate of Soda. Dis. Bone-black. Mur. of Potash.	*At Harvest.*					
		Water,	42.63	43.74	43.19	1.11	.56
		In Water-free Substance.					
		Nitrogen,	.78	.75	.77	.03	.02
		Fat,	2.21	2.04	2.13	.17	.09
		Fiber,	36.73	36.24	36.48	.49	.25
		Ash,	5.59	6.20	5.90	.61	.31
H.	Plaster.	*At Harvest.*					
		Water,	26.79	27.43	27.11	.64	.32
		In Water-free Substance.					
		Nitrogen,	.66	.75	.71	.09	.05
		Fat,	1.93	2.12	2.03	.19	.10
		Fiber,	36.74	37.05	36.89	.31	.16
		Ash,	5.45	5.58	5.52	.13	.07

TABLE 44.

Variations in Composition of Samples of Hay. Percentages of Water at Harvest, and of Nitrogen, Fat, Fiber, and Ash in Water-free Substance of Triplicate Samples, and the Variations in Percentages.

Plot No.	Fertilizers.		SAMPLES.				VARIATIONS.		
			A.	B.	C.	Average.	Extreme.	Above Average.	Below Average.
			%	%	%	%	%	%	%
0	Unmanured.	*At Harvest.*							
		Water, - -	24.17	19.37	22.05	21.86	4.80	2.31	2.49
		In Water-free Subst.							
		Nitrogen, - -	1.16	1.13	1.22	1.17	.09	.05	.04
		Fat, - - -	3.72	3.68	3.50	3.63	.22	.09	.13
		Fiber, - -	31.45	31.16	31.07	31.23	.38	.22	.16
		Ash, - -	5.02	4.83	5.05	4.97	.22	.08	.14
00	Unmanured.	*At Harvest.*							
		Water, - -	24.06	24.37	24.63	24.35	.57	.28	.29
		In Water-free Subst.							
		Nitrogen, - -	1.14	1.20	1.21	1.18	.07	.03	.04
		Fat, - - -	3.61	4.28	3.76	3.88	.67	.40	.27
		Fiber, - -	31.59	31.16	31.20	31.32	.43	.16	.27
		Ash, - -	4.92	5.07	5.21	5.07	.29	.14	.15
6*a*	Dis. Bone-black. } Mur. of Potash. } *	*At Harvest.*							
		Water, - -	25.23	24.98	26.97	25.73	1.99	1.24	.75
		In Water-free Subst.							
		Nitrogen, - -	1.28	1.27	1.40	1.32	.13	.08	.05
		Fat, - - -	3.07	2.98	3.57	3.21	.59	.36	.23
		Fiber, - -	32.95	33.24	32.16	32.78	1.08	.46	.62
		Ash, - -	5.86	5.72	5.87	5.82	.15	.05	.10
6*b*	Mix. Min., as 6*a*.	*At Harvest.*							
		Water, - -	20.42	19.78	21.91	20.70	2.13	1.21	.92
		In Water-free Subst.							
		Nitrogen, - -	1.27	1.33	1.35	1.32	.08	.03	.05
		Fat, - - -	3.31	3.52	3.94	3.59	.63	.35	.28
		Fiber, - -	32.01	32.10	32.16	32.09	.15	.07	.08
		Ash, - -	5.67	5.84	6.00	5.84	.33	.16	.17
		NITRATE OF SODA GROUP.							
7	Mix. Min., as 6*a*, 25 lbs. Nitrogen.	*At Harvest.*							
		Water, - -	25.97	26.95	27.69	26.87	1.72	.82	.90
		In Water-free Subst.							
		Nitrogen, - -	1.34	1.37	1.31	1.34	.06	.03	.03
		Fat, - - -	3.77	3.49	3.85	3.70	.36	.15	.21
		Fiber, - -	33.87	33.64	33.11	33.54	.76	.33	.43
		Ash, - -	5.60	5.67	5.37	5.55	.30	.12	.18

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* Mixed Minerals.

TABLE 44.—*(Continued.)*

Plot No.	Fertilizers.		Samples.				Variations.		
			A.	B.	C.	Average.	Extreme.	Above Average.	Below Average.
			%	%	%	%	%	%	%
8	Mix. Min., as 6*a*. 50 lbs. Nitrogen.	*At Harvest.*							
		Water, - -	29.83	29.09	28.29	29.07	1.54	.76	.78
		In Water-free Subst.							
		Nitrogen, - -	1.31	1.31	1.26	1.29	.05	.02	.03
		Fat, - - -	3.56	3.27	3.65	3.49	.38	.16	.22
		Fiber, - -	34.58	34.93	34.32	34.61	.61	.32	.29
		Ash, - -	5.17	5.03	5.15	5.12	.14	.05	.09
9	Mix. Min., as 6*a*. 75 lbs. Nitrogen.	*At Harvest.*							
		Water, - -	26.18	27.64	27.16	26.99	1.46	.65	.81
		In Water-free Subst.							
		Nitrogen, - -	1.44	1.49	1.48	1.47	.05	.02	.03
		Fat, - - -	3.23	3.13	4.16	3.51	1.03	.65	.38
		Fiber, - -	34.70	34.48	34.48	34.55	.22	.15	.07
		Ash, - -	5.08	5.25	5.13	5.15	.17	.10	.07
		SULPHATE OF AMMONIA GROUP.							
10	Mix. Min., as 6*a*. 25 lbs. Nitrogen.	*At Harvest.*							
		Water, - -	23.40	23.89	23.70	23.66	.49	.23	.26
		In Water-free Subst.							
		Nitrogen, - -	1.20	1.20	1.22	1.21	.02	.01	.01
		Fat, - - -	3.41	3.28	3.85	3.51	.57	.34	.23
		Fiber, - -	34.82	33.79	34.00	34.20	1.03	.62	.41
		Ash, - -	5.28	5.31	5.47	5.35	.19	.12	.07
11	Mix. Min., as 6*a*. 50 lbs. Nitrogen.	*At Harvest.*							
		Water, - -	23.86	24.04	23.66	23.85	.38	.19	.19
		In Water-free Subst.							
		Nitrogen, - -	1.33	1.31	1.37	1.34	.06	.03	.03
		Fat, - - -	5.90	3.53	3.64	4.36	2.37	1.54	.83
		Fiber, - -	34.07	34.57	33.31	33.98	1.26	.59	.67
		Ash, - -	5.23	5.01	5.35	5.20	.34	.15	.19
12	Mix. Min., as 6*a*. 75 lbs. Nitrogen.	*At Harvest.*							
		Water, - -	22.64	22.13	21.33	22.03	1.31	.61	.70
		In Water-free Subst.							
		Nitrogen, - -	1.46	1.52	1.42	1.47	.10	.05	.05
		Fat, - - -	3.33	3.44	4.20	3.66	.87	.54	.33
		Fiber, - -	34.23	33.07	33.75	33.68	1.16	.55	.61
		Ash, - -	5.10	5.17	5.03	5.10	.14	.07	.07

TABLE 45.

Percentages of Water at Harvest, and of Nitrogen, Fat, Fiber and Ash in Water-free Substance of Duplicate Samples of Legumes, and the Extreme and Mean Variations in Percentages.

Kind of Plant.		A.	B.	Average.	Variations.	
					Minimum.	Maximum.
		%	%	%	%	%
Vetch.	*At Harvest.*					
	Water,	81.35	78.22	79.79	3.13	1.57
	In Water-free Substance.					
	Nitrogen,	3.27	3.04	3.16	.23	.12
	Fat,	2.18	1.89	2.04	.29	.15
	Fiber,	31.69	28.78	30.24	2.91	1.46
	Ash,	13.07	18.75	15.91	3.68	1.84
Clover.	*At Harvest.*					
	Water,	78.73	75.29	77.01	3.44	1.72
	In Water-free Substance.					
	Nitrogen,	2.88	2.81	2.85	.07	.04
	Fat,	3.12	3.25	3.19	.13	.07
	Fiber,	27.67	28.91	28.29	1.24	.62
	Ash,	10.01	10.52	10.27	.51	.26
Clover.	*At Harvest.*					
	Water,	86.77	85.24	86.01	1.53	.77
	In Water-free Substance.					
	Nitrogen,	2.78	2.71	2.75	.07	.04
	Fat,	2.95	2.47	2.71	.48	.24
	Fiber,	29.95	31.58	30.77	1.63	.82
	Ash,	9.52	10.65	10.09	1.13	.57
White Lupine.	*At Harvest.*					
	Water,	85.19	85.68	85.44	.49	.25
	In Water-free Substance.					
	Nitrogen,	82.44	2.54	2.49	.10	.05
	Fat,	2.47	2.29	2.38	.18	.09
	Fiber,	35.67	34.17	34.92	1.50	.75
	Ash,	11.42	10.91	11.17	.51	.26
Yellow Lupine.	*At Harvest.*					
	Water,	89.20	89.04	89.12	.16	.08
	In Water-free Substance.					
	Nitrogen,	2.78	2.57	2.68	.21	.11
	Fat,	2.10	2.45	2.28	.35	.18
	Fiber,	31.63	31.35	31.49	.28	.14
	Ash,	10.91	9.33	10.12	1.58	.79

TABLE 45.—*(Continued.)*

Kind of Plant.		A.	B.	Average.	Variations. Minimum.	Variations. Maximum.
		%	%	%	%	%
Blue Lupine.	*At Harvest.*					
	Water,	86.21	87.26	86.74	1.05	.53
	In Water-free Substance.					
	Nitrogen,	2.27	2.49	2.38	.22	.11
	Fat,	2.14	2.31	2.23	.17	.09
	Fiber,	31.47	31.66	31.57	.19	.10
	Ash,	11.89	12.18	12.04	.29	.15

TABLE 46.

Variation in Percentage in Samples from Same Plots.

	Corn.			Stover.			Hay.		
	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.
	%	%	%	%	%	%	%	%	%
At Harvest.									
Water,	.02	2.13	.87	.41	10.30	4.09	.38	4.80	1.64
In Water-free Substance.									
Nitrogen,	.00	.26	.08	.01	.10	.06	.02	.13	.07
Fat,	.01	.37	.15	.08	.55	.26	.22	2.37	.77
Fiber,	.01	.11	.05	.09	1.73	.62	.15	1.26	.71
Ash,	.01	.13	.07	.10	.82	.50	.15	.34	.23

The above table (46) gives in condensed form the extremes and means of variation in the percentage results of the analyses of duplicate samples of corn and stover from ten different plots, and those of the analyses of triplicate samples of hay also from ten plots.

The variations in water content of the different samples at time of harvest are much larger than the other variations. This was expected, because water is the most varying constituent in vegetable tissue.

It will be observed that the variations in percentages of water and of most of the other ingredients in corn are much less than the variations in composition of either grass or stover. From this it does not follow that a more representative sample was obtained of corn than of grass or stover, but the better agreement in composition of duplicate samples is doubtless due, in part at least, to the fact that the seed of a given crop has a more uniform composition than the other parts of the plant.

To obtain an idea of the relative accuracy of field sampling, it is desirable to compare variations between duplicate samples with the variations in composition found between the averages of the different plots in a field.

The following table (47) gives the minimum and maximum percentage composition of the crop from the same plots from the analyses of which the variations given in table 46 were obtained, and assumes that the average of the analyses of the duplicate (or triplicate) samples represents this composition.

TABLE 47.

Minimum and Maximum Percentage of Water at Harvest, and of Nitrogen, Fat, Fiber, and Ash in Water-free Substance of Corn, Stover, and Hay, and their Extreme Variations.

	CORN (GRAIN).			STOVER.			HAY.		
	Minimum.	Maximum.	Extreme Variation.	Minimum.	Maximum.	Extreme Variation.	Minimum.	Maximum.	Extreme Variation.
	%	%	%	%	%	%	%	%	%
Water at Harvest, -	21.03	23.99	2.96	24.54	43.19	18.65	20.70	29.07	8.37
In Water-free Subst'ce.									
Nitrogen, - -	1.63	1.83	.20	.70	.90	.20	1.17	1.47	.30
Fat. - - -	5.05	5.35	.30	1.59	2.23	.64	3.21	4.36	1.15
Fiber, - -	1.36	1.53	.17	36.48	38.30	1.82	31.23	34.61	3.38
Ash, - -	1.48	1.62	.14	4.95	6.12	1.17	4.97	5.84	.87

In the following table the maximum variations in percentage composition found between the duplicate (or triplicate) samples of corn, stover, and hay given in table 46 are compared with the maximum variations of composition of the crop from the various plots which are given in table 47.

	CORN.		STOVER.		HAY.	
	Between Duplicate Samples from same Plot.	Between Different Plots.	Between Duplicate Samples from same Plot.	Between Different Plots.	Between Triplicate Samples from same Plot.	Between Different Plots.
	%	%	%	%	%	%
Water at Harvest, - - -	2.13	2.96	10.30	18.65	4.80	8.37
In Water-free Substance.						
Nitrogen, - - - -	.26	.20	.10	.20	.13	.30
Fat, - - - - -	.37	.30	.55	.64	2.37	1.15
Fiber, - - - -	.11	.17	1.73	1.82	1.26	3.38
Ash, - - - - -	.13	.14	.82	1.17	.34	.87

In the above table it will be observed that the differences in percentage composition of the duplicate samples of corn taken from the same plots are in some cases wider, and in others nearly as wide, as those between the average composition of the yields of the different plots. The differences in percentages of fat (ether extract) may be neglected, since the amount of the extract obtained seems to be dependent upon several factors (such as length of time after harvest, length of time after preparation of sample, etc.), other than the presence of definite amounts of material soluble in pure ether. The variations in percentages of fiber and ash are within the range usually allowed in duplicate analyses of the same sample.

In the case of the corn there seem to be as great, or even greater, differences in composition of water-free substance of the crop due to errors of sampling than are due to the use of different fertilizers used in growing the crop on the different plots. This is also true to quite an extent of the stover.

The experiment (soil test by Mr. C. E. May, see pages 68 and 69) from which these samples of corn and stover were taken was one in which there was little response to fertilizers. The yield was large, even on the unmanured plots, and there were very little differences in composition of the crop from the different plots. In such an experiment as that of Mr. Dean's in 1890 (see page 110), or in his special nitrogen experiment of 1889,* in which the variations in percentage composition between the crop

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from the different plots were large, it is probable that the differences in composition of the samples from the same plot would not so nearly equal those between the different plots of the field, as in the case of the corn and stover above.

In the case of hay, the differences due to the effect of fertilizers were apparently greater than in that of the maize, and the differences in composition of the water-free substance of the crop from different plots were sufficiently large to be evident in spite of the errors of sampling.

Do the above results mean that the errors of field sampling are so great as to nearly destroy the value of results of analysis so far as variations in composition of the crop due to fertilizers are concerned? In the case of such an experiment as the above on corn, such certainly appears to be the case. But, as stated above, the variations found in the composition of the crop from the different plots in this experiment are small, and it probably would be true that the results of analyses of different samples from the same plots, in an experiment where there were wide variations in composition of crop from different plots, would not show wider variations than these did; and then the variations in composition due to fertilizers or other causes would be more conspicuous. In other words, the variations in actual average composition would be greater than the error due to sampling. While it is probably true that the results of analyses of the crop as indicated by a single experiment may, even with no more accurate sampling than that of the above experiments, partially indicate differences in composition (if they are quite marked) of the crop from different plots, it is very desirable that the errors due to sampling be reduced to a minimum.

There would seem to be only two ways to reduce the errors of field sampling to a satisfactory minimum: either to take more samples from each plot or improve the methods of sampling. The latter is more desirable, if attainable. Increasing the number of samples diminishes the probable error in the average.

The conclusions (see Reports of this Station for 1888 and 1889) regarding the relation of composition of corn to fertilizers applied were drawn from quite a number of analyses of crops from plots treated in the same way, and it is probable that the average of these results is not greatly in error. The objection to this method of reducing the error of field sampling is the greatly increased amount of both field and laboratory work.

The second method, and the better if attainable, to reduce these errors, is improvement in method of sampling.

There are two ways in which a sample of a crop may be obtained,—the one, as described in the earlier part of this paper, consisting of selecting representative handfuls from different parts of the crop after cutting; the other, selecting an apparently representative area, cutting it, and using the whole crop from that area as the sample. Of course, there are many possible combinations of these two methods, such as selecting a number of small areas and combining the crops from these into one sample, or selecting a large area and from the crop selecting a small sample.

Several samples of legumes were taken for analyses by cutting the crop from small areas. An area of four square feet, as representative as practicable, was selected and cut, and the whole yield taken as a sample. Table 45 gives the results of the analyses of duplicate samples taken in this way, with the variations in percentage composition. It will be noted that the variations are large,—larger on the average than those taken in the method used in obtaining the maize and hay samples described above. That this should be the case is not surprising, since the smallness of the number of plants growing on the given area, the uneven distribution of fertilizers and consequent variation in composition of the plants on different areas, the difficulty of cutting the plants so as to have the same relative proportion of stem in each case, etc., contribute to the unevenness of the samples.

To increase the size of the sample is doubtless the best way, all things considered, for reducing the errors of field sampling. The ideal way would be to analyze the total yield. The difficulty with large samples, such as a tenth of the yield of an ordinary plot, is in the handling of so much material. In the case of such plants as grass, oats, wheat, etc., where a sample of 10 or 15 pounds includes hundreds of individuals, it is not difficult to take samples that should be representative. In the case of maize, a far greater weight would have to be taken to overcome errors.

PRACTICAL CONCLUSIONS.

As a result of our experience in sampling field crops for analysis, the following seems to us the better way and will be used in our work the coming season.

Maize.—Select for harvesting the crop and taking samples a bright clear day, following two or more dry days. Commence work as soon as the dew is off. In the case of ten or more plots to be harvested, there should be three trained men besides two or three assistants. One of the men should attend to the field weighings, the other two to sampling. As soon as the field weighings on a given plot are made, each sampler should select a sample from every stook, representing the inside as well as the out, of one-twentieth of the crop in the stook, and after these are thus taken they should be combined into one final field sample including about one-tenth of the entire yield. Weigh, husk, and then weigh the ears and stover separately. Take all of the ears for the laboratory sample. Cut the stover into pieces not more than one inch in length, and take a laboratory sample of about five pounds. Proceed in this way over all of the plots, making field weighings no faster than the samples are taken.

On receipt at the laboratory the sample should be weighed, the corn shelled, and weight of corn and of cobs taken.

Hay.—When the hay is in proper condition for putting into the barn, rake into windrows and have each of the two samplers take small handfuls from each windrow, taking about one-fortieth of the yield. The samples are best collected in bags or sacks. The two samples should be combined into one, thus including in the field sample about one-twentieth of the crop. This may be weighed with the hay on the wagon, or separately, and the weights added to the field weight of hay. The hay should be cut into inch pieces (or less), and a sample of about ten pounds first selected, and from this a final laboratory sample of about five pounds taken.

Oats.—The oats should be threshed at once after weighing, and samples taken, by one or more samplers, of the straw and the oats, in such amount that the final sample shall represent about one-twentieth of the grain, and of the straw. These should be sub-sampled, and a final laboratory sample obtained, as in the case of hay above.

In the case, for instance, of one of our Special Nitrogen experiments on corn with 16 or 20 plots of which samples must be taken in a short October day, between the time when the dew is off in the morning and dark, to get samples as large and carefully taken as is desirable, the services of three or more trained men are required. This is, in short, one of the very many ways in which experience emphasizes the need of improvement in methods, but at the same time shows the great increase of labor and expense which that improvement involves.

RIPENING OF CREAM.

BY

H. W. CONN, PH. D.

[During the past three years, investigations on the bacteria of milk have been conducted, in behalf of the station, by H. W. Conn, Professor of Biology in Wesleyan University. In Bulletin No. 4, and in the Annual Report of the Station for 1889, brief accounts of preliminary experiments upon the relation of bacteria to milk and various other dairy products were given. The experiments there mentioned have been continued and are still in progress, and though not yet complete, certain results of value and interest have been reached. Various matters have been studied, but the experiments have been directed chiefly to the study of the process known as the ripening of cream. The following is a summary of some of the more interesting results of the work:]

CREAM.

It will be well at the outset to ascertain what is known of the composition and structure of cream. Cream has the same chemical composition as milk with, however, a greater proportion of casein and albumen, and a much greater proportion of fat. The fat is always separated from the rest of the milk in the form of cream, by means of its lesser specific gravity, and in thus separating it brings with it much of the casein and albumen of the milk, with considerable quantities of the salts and sugar. The chemical composition of cream, being thus so similar to that of milk, need not be dwelt upon further in this place.

A matter of great importance in its relation to butter, is the condition in which the fat exists in the cream. By the use of the microscope it is found that the fat of milk and also of cream is in the form of small spherical globules, varying in size from a thousandth to a hundredth of a millimeter. In newly drawn milk, the fat of the globules is certainly in a liquid condition, but in cream the fat is at least partly solidified. This is shown by the shape of the fatty globules in cream. If they were liquid they would of course be spherical, but in cream many of them assume an irregular shape. Several of them are frequently fused together, looking very much like a mass of budding yeast cells. They seem to be soft enough to adhere but too hard to fuse into a single droplet. If the fat were still liquid, the drops upon fusing would unite into single drops of larger size, like the fusion of globules of mercury. Instead of this, they adhere to each other, only partly fusing and still distinct. This does not apply to all of the cells of the cream, for many of them remain as distinct spherical globules.

It has long been a puzzle why the fat globules thus remain isolated from each other in milk and cream, without uniting. When fat is shaken up with water it will divide into fine droplets, forming an emulsion, but these soon unite again together into a mass at the surface. The emulsion of the fat in milk, however, remains permanent if left undisturbed, churning being necessary to cause the globules to unite together. In explanation of this fact, some have believed that there is around each globule of fat a sac of some sort, which prevents their uniting. Early microscopists even regarded the globules as of the nature of cells. Turpin [*37], writing about the time when the cell doctrine was first conceived, thus regarded them, and he further thought that the fat globules were capable of germination and growing into bacteria and moulds.

The idea that they were true organic cells was soon abandoned, and it was then supposed that there was an albuminous envelope around the fat. Ascherson [40], showed that when fat is shaken in an alkaline solution of albumen, the globules surrounded themselves with an envelope of the coagulated albuminates, and a similar action has been supposed to take place in milk. According to the researches of Wittich, the formation of this membrane seemed to be due to the fact that at the boundary between the fat and the albumen a portion of the fat is saponified by the action of the alkali, and some of the albumen is precipitated in connection with the action. Kuhne [68] subsequently showed that no such membrane is formed by the use of potassium albuminate, and thus the matter from this standpoint was left undecided.

Some of the earlier observers thought that by staining methods they could demonstrate the presence of a membrane around the fat. Simon [40] described such a membrane, and Moleschott [52], Furstenburg [68], and Schwalbe [72], thought

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*For reference to this and other notes, see p. 161 at end of this paper.

they could see the membrane by the use of microscopic methods. In most cases, however, this membrane was seen only after the application of staining reagents, and thus these observations were all open to the objection that the membranes seen were artificial products, resulting from the precipitation of the casein by the chemical reagents used. Haidenhain [80] found that when sections of the milk gland were treated with turpentine, the fat dissolves, leaving little cavities in the cells. This, of course, indicates that there are no membranes around the fat while in the mammary cell, but is of no value as indicating the condition of the fat in the milk. DeSinty [74] studied the staining property further, and found that if fresh milk is stained with a water solution of aniline red, no such membrane can be seen; if, however, the milk is allowed to stand for a while, a red envelope will appear around many of the globules. The necessary conclusion is, that the envelope which the earlier observers thought they found, was a precipitation around the fat of some thing which had been dissolved in the milk, and that it was therefore not a normal product.

The envelope theory has been argued from still another series of experiments. It has been found that when ether is added to milk, the fat will dissolve very slowly, and a long time is required for its complete solution. If, however, a little acetic acid is previously added, the solution of the fat occurs very rapidly. This was first shown by Henle [39], and Lehmann [50] subsequently showed that sodium and potassium hydrates, and phosphoric and sulphuric acids have the same effect. This result was supposed to be due to the solution of the albuminous membrane by the acid. The conclusion is not warranted, however, for if the quantity of ether be very large, the solution of the fat occurs readily enough.

The failure to demonstrate satisfactorily the envelope theory has led in more recent times to the attempt to account for the continued emulsion of the fat by the physical condition of the liquid in which it is suspended. Brucke [47], so long ago as 1847, explained the emulsion of the fat upon the principle of its specific gravity. According to him, the specific gravity of the fat is slightly less than that of the albuminous envelope around it, and this produced a free floating of the globules. Hoppe [59] adopted a similar explanation.

Donne [44] was the first to abandon the membrane theory completely and find in the liquid part of the milk the reason for the emulsion. He regarded the casein as not forming a complete solution, but as partly granular, and he supposed that the solid portion keeps the fat in emulsion. Bouchardat and Quevenne [57] regarded the casein as viscous, and found in this fact the reason for the emulsion.

Zann [66] experimented by filtering milk through a porcelain cylinder, and found that he could completely separate the casein and obtain a filtrate that was clear and contained nothing but the serum albumen. Hammersten [74] reached similar conclusions. It is plain that this incomplete solution of the casein may be the reason for the failure of the fat globules to fuse with each other. Doubt is, however, thrown on the value of these results by the previous observation of Soxhlet [42] that the presence of fat may prevent the filtration of potassium albuminate, which is otherwise easily filtered. It may therefore be that the casein is really in solution, but is prevented from filtering by the presence of the fat.

Haidenhain [80] concluded that it is the casein concerned in rendering the emulsion permanent, from the fact that he could not procure an emulsion of butter-fat with the casein-free solution obtained by filtering milk through porcelain. Since the milk has lost only its fat and casein by such filtration, the conclusion was clearly indicated that it must be the casein that is directly concerned in the emulsified condition of the fat. A confirmation of this fact is found in the observation of Soxhlet [76] that if the casein of milk is first precipitated by rennet, the fat will subsequently dissolve readily in ether.

Martiny [71] added further evidence against the membrane theory by manufacturing milk artificially. By shaking fat with serum, he produced an emulsion which remained permanent like milk. He concluded that the fat globules are simply masses of fat to which a little casein adheres sufficiently to prevent their ready fusion.

Duclaux [87] has also succeeded in making an artificial milk. He shakes butter-fat with a soapy solution which is somewhat viscous, and has about the same surface tension as the fat. The emulsion obtained resembles milk in many respects. The fat rises to the surface like cream and the globules do not readily fuse together.

From these various facts, the opinion has arisen in recent years that the emulsion of milk is not due to any membrane round the globules, but to the physical law of liquids. Druggists can make a permanent emulsion of fat in a gum solution, and here there is no question of the presence of a membrane. In the milk the fat is of about the same density as the liquid in which it floats, and the large quantity of liquid compared with the small quantity of fat prevents the globules from coming in contact to any great extent. The fat rises slowly to the surface of the cream, but though the globules are now in close proximity to each other, they do not fuse. The difference in the constitution of the fat and the milk serum must produce a surface tension around the fat globules which it requires some little force to overcome. Just as a mass of soap bubbles is prevented from fusing together by the tension of their surfaces, so the fat globules, surrounded as they are by the liquid casein, are prevented from fusing by surface tension. A little shaking, or the action of chemicals on the casein, will tend to break up the surface films and thus destroy the surface tension allowing the globules to fuse. According to Duclaux [87] the great permanence of the emulsion in the case of milk is due to the fact that the surface tension of the fat is nearly the same as that of the liquid surrounding it, in conformance with the law that the more nearly equal the density of the liquid, the greater the difficulty the globules experience in uniting. When oil is shaken with water, the emulsion lasts only a short time, but when shaken with the white of an egg it lasts much longer, and as above mentioned, when shaken with the proper solution of soap, it is nearly permanent.

While there can be little doubt that the matter of surface tension has much to do with the emulsified condition of milk, there are other facts which indicate that this is not the whole of the matter. In the first place, this would leave no explanation of the fact that sweet cream is only churned with difficulty, while ripened cream churns much more readily. Nor does this idea take into consideration the question of the solid or liquid condition of the fat. That the fat is liquid when the milk is drawn is evident. Soxhlet [76] was indeed of the opinion that the fatty globules in milk and cream are always in the liquid condition, and that only excessive cold or shaking will cause them to solidify. He pointed out that even water will remain liquid at temperatures considerably below the freezing point, if the water exist in the form of minute droplets. The smaller the droplets the lower the temperature reached before they will freeze. According to Soxhlet [76], therefore, the fat of milk is liquid at temperatures far below the melting point of fat, and churning is simply solidifying the globules by shaking them together. But as pointed out above, the globules in the cream before churning are at least partly solid, as is indicated by their shape, and, further, this explanation of Soxhlet will not explain the difficulty of churning sweet cream.

Another series of facts has been advanced which indicate that there is really some material in the milk preventing the globules from fusing as readily as they would naturally do. Kehrer [71] observed that the fatty globules in milk do not keep separate from each other as entirely discrete spheres, but adhere together in masses which move in bulk through the liquid. The relative position of the globules in each mass is fixed. The truth of this observation can be ascertained by any one who has a microscope at his command. This fixing of the globules of course indicates that there is something binding them together. Kehrer thought that the globules are fixed by a slimy substance which is invisible until coagulated by some reagent. By such coagulation he could demonstrate a granular mass, which he regarded as coagulated casein, and from the whole of his experiments he concluded that the casein in the milk is in the form of solid suspended particles. Haidenhain [80] subsequently showed that this grouping of the globules does not appear in perfectly fresh milk, but only after the milk has been standing for a time. He therefore regarded this phenomena as the beginning of the coagulation of milk, and did not regard it as an adequate explanation of the emulsion of milk fat.

From these well authenticated experiments, it is thus evident that in manipulating the fatty globules of cream, we are dealing with something more than globules kept from fusing by their surface tensions merely. Even though the physical explanation may be sufficient to account for the emulsion of milk, it is certain that by the time that the cream has been separated from it there is some material which binds the fat globules into groups and still keeps them from actually touching so as to fuse.

Recently, Babcock has independently confirmed these observations and has conceived an entirely new explanation. In his first paper [86], he concluded that the emulsion of milk is very like a physical emulsion. Later [89], however, he argued that there occurs in the milk, shortly after it is drawn from the cow, a change which is analogous to the clotting of blood. He finds, as did Haidenhain, that at the outset the globules are separate, but soon become collected into groups. He supposes that there is formed in the milk shortly after it is drawn from the cow, a network of fine fibers like those which form in a clot of blood. The fibrous material thus formed in milk is very small in amount, so small indeed as to be invisible even to the microscope. It is sufficient, however, to render the milk slightly less limpid. The network thus formed, he regards as identical with fibrin, and calls it by that name. According to Babcock, it is this fibrin which is the agent in entangling the fat globules and making them adhere into groups. The formation of fibrin in the blood, as is well known, can be prevented by the addition of saturated solutions of neutral salts. Babcock argues that it ought also to do so in milk, and he finds that, if a neutral salt is added to the milk, immediately when it is drawn, the fat globules will not collect into the characteristic masses, but will remain distinct and isolated. This is of course interpreted as due to the non-formation of fibrin. Babcock is unable to demonstrate the presence of fibrin directly, but he gives considerable evidence that there is formed in the milk a proteid which is either fibrin or behaves very much like it in its chemical reactions. Indeed, it would seem quite likely that a material like fibrin would be formed in milk. Most animal tissues undergo post-mortem changes resulting in stiffening. The presence of serum albumen in milk, so nearly identical with the serum albumen of the blood, the great quantity of material which must be taken from the blood during the secretion of the milk, and the fact that the secretion of the milk is accompanied by a more or less breaking down of the mammary tissue, would render it not improbable that some of the fibrin forming elements may get into the milk and there produce a slight clotting. That this material is fibrin is perhaps not yet settled. But the experiments of Kehrer [71], Haidenhain [80], and Babcock [89] certainly show that there is formed in milk, shortly after the milking, an impalpable material, proteid in nature, which unites the globules into masses, and has doubtless no little influence in preventing the fusion of the globules with each other.

It is somewhat strange to notice a recent revival of the abandoned membrane theory by Bechamp [88]. Bechamp does not regard the milk as simply an emulsion due to the tension of the surfaces, but thinks that the fat globules are of the nature of cells and that they are enclosed in a sac. He finds that upon drying fat a part remains as an infusible portion, which is in the form of a sac, and which he supposes normally to hold the fat proper like a sponge. This infusible portion is not casein, but is regarded as being of an epidermal nature. Its amount is about one three-hundreth of the amount of the fat. Bechamp finds further that ether does not completely destroy the fat globules. It dissolves the fat, but leaves a thin membrane undissolved, and this is visible with a microscope after the treatment of the fat with ether. This had been previously shown by Furstenburg [68]. It was subsequently denied by Soxhlet [76], who stated that the explanation is simply that the fat dissolves slowly, and these so-called sacs are the undissolved fat globules which disappear with a subsequent treatment with ether. Seemingly Bechamp has therefore added nothing to the question by these observations.

It will be seen from the review thus given, that the verdict of science upon this vexed question is at the present time somewhat as follows: The fat globules are not cellular in their structure. There is no good reason for believing that there is formed around them, either before being drawn from the cow, or afterward, anything in the form of a membrane. The permanent emulsion of the milk is probably explained, largely at least, by the laws of liquids. The film of casein around the fat has a surface tension different from that of the fat, and this tension must be overcome in order that the fat globules may fuse together. Anything which would tend to rupture that film would assist in the fusion and aid the solution of the globules, and hence the addition of acids or a shaking will tend to make the fat globules fuse together. Lastly, it would seem that a change takes place in the milk shortly after being drawn. It becomes less liquid, and a slimy substance is formed, which causes the globules to unite together into groups. This substance may be fibrin, and is at all events of a proteid nature. In all cream, of course, this material will be present, and its presence is an important factor in the consideration of the treatment of cream in butter making.

A special study of churning will be reserved for a future paper. For our present purpose it is sufficient to notice that the essential feature of the process is the union of the fatty globules together into large masses which become bulky enough to be separated from the liquid part of the cream and thus form butter. It is a well-known fact that the churning and subsequent washing of butter does not completely free the butter fat from the other materials associated with it in the cream. Good butter should contain about 85 per cent. of fat, the other 15 per cent. being water, together with various salts and casein or other nitrogenous matter. In good butter the casein is from .2 to 1 per cent., and even the most thorough washing will not avoid the presence of considerable nitrogenous matter, which is the chief cause of the tendency of butter to become rancid. Anything that decreases the amount of nitrogenous matter will increase the keeping property of the butter. If, for instance, the butter be melted at the temperature of 85° C. the casein will settle to the bottom, leaving the butter fat in a purer condition. Such butter fat will keep sweet much longer than ordinary butter.

In addition to these substances, butter always contains a small amount of material which gives its peculiar aroma or flavor. It is usually believed that the flavor is due to certain volatile fatty acids, among which are caprilic, caprionic, caproic, butyric, and others. If the flavor of the butter depends upon the presence of these substances, it is evident that their proper production in the cream is a matter of utmost importance to the butter maker. There is very little doubt that it is during the ripening of the cream that these flavoring substances are formed, for it has been shown by Heintz [53] they are not present in fresh milk.

THE RIPENING OF CREAM.

With this preliminary account of the composition and structure of cream, we are prepared to study its ripening. It is customary everywhere among butter makers to allow cream to stand for a longer or a shorter period, for the purpose of "ripening" or "souring" as the Germans say, before the churning is begun. In this process the cream changes its character noticeably. It becomes acid and slightly thickened, and acquires a pleasantly sour odor. The odor is, however, quite different from that of sour milk, indicating that something besides the souring has taken place. The extent to which the ripening is allowed to continue is quite different in different dairies. In the dairy of the small farmer the cream is kept for several days, and the result is sometimes a cream so ripe that it is almost too stiff to stir with a spoon.

In larger dairies and in creameries, the ripening is not continued so long, and the cream is churned while it is still freely liquid. The extent of the ripening will vary with the temperature, and the best results are obtained by creameries which have appliances for keeping a uniform temperature. It is largely the uniformity of ripening which is the foundation of the uniformity of the butter product from creameries.

There seem to be two chief objects attained by the ripening of cream. First: Cream thus ripened churns more easily and the butter comes more readily. As a corollary of this fact, it is found that more butter can be obtained from cream if it is first ripened. This is especially true of cream which is separated from the milk in the ordinary method of setting. Where the cream is separated by the centrifugal machine, there does not seem to be so much need of the ripening for these purposes. The experiments of Meyers [90], and recent experiments in Denmark (see review in Milchzeitung, 1891,) indicate that sweet cream from the centrifugal machine can be readily churned. Second: The flavor of the butter made from ripened cream is superior to that made from sweet cream. It is the general experience that the desirable butter aroma does not appear in sweet cream butter. Such butter having a taste of sweet cream is said to taste "flat." The proper butter flavor only appears after ripening.* On the other hand, if the ripening continues too long, decomposition of the cream will set in, and the flavor of decomposition will be carried over into the butter.

It has been generally supposed that the ripening process was one depending chiefly or wholly on the formation of acid. In Germany, the process is known as the "souring" of cream, and attempts have been made to determine the amount of ripening by estimating the quantity of acid. With this idea it has frequently been the custom to add a little lactic acid to the cream in order to hasten the process. While the addition of the acid does certainly hasten the souring, it does not accomplish the other purposes of the ripening, for the whole process is a complicated one connected with bacteria growth, and the formation of the acid is only a part of it.

That the ripening of cream is a process connected with bacteria growth follows from the conditions under which it is accomplished. Of the immense number of bacteria which are in milk, many will, of course, get into the cream and will grow rapidly during the ripening process. The souring is certainly due to bacteria growth, for it has been conclusively shown that the formation of lactic acid in milk products is always caused by bacteria. It is further found that all conditions which hasten bacteria growth also hasten the ripening of the cream.

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*In the recent experiments in Denmark referred to, it is stated that the flavor of the sweet cream butter was not noticeably different from that made from ripened cream. But this result is so different from the universal experience that it cannot be accepted without fuller details.

So far as I am aware, only two experimenters have studied the ripening of cream in the light of modern bateriological knowledge. The first is W. Storch, of Copenhagen ; the second, H. Weigmann-Kiel. In his first paper [77], Storch studied the differences between butter made from sweet and sour cream. This paper I have not seen. Later [90], he undertook the study of cream for the purpose of finding, if possible, some means for giving greater uniformity in the results of butter makers. He soon concluded that the source of the numerous "effects" ["*Fehler*"] was in the ripening process and connected with the growth of mischievous bacteria. He found that the occasional production of tallowy butter, or oily butter, was connected with definite species of bacteria which had grown in abundance in the cream from which the butter was produced. Acting upon the suggestion thus given, he concluded that the taste of the butter was due to bacteria growth in the cream, and he therefore endeavored to find some species which, by growing in the cream, would give a satisfactory aroma to the butter. For this purpose he first isolated bacteria from butter milk, and others from a superior quality of butter. With the bacteria thus isolated, he found that he could sour the cream with no difficulty. Cream was first sterilized and then inoculated with the pure cultures of these bacteria and then ripened. The cream churned rapidly enough after such ripening, but the butter obtained did not have the proper aroma. Returning to the study of cream, therefore, he next obtained bacteria from ripening cream of a first-class creamery. In this he found seven species, and among them was one of the lactic acid forming class, which experiment showed would give the proper aroma to butter. By inoculating this species into pasteurized cream, he claimed greater certainty of good results than by the ordinary process of ripening.

During the last year, Weigmann-Kiel [90] has adopted Storch's methods. He has also procured artificial cultures which he claims give the proper aroma to butter. He has supplied pure cultures of this species to several creameries, and the use of the ferment is becoming common in his neighborhood. The claim which is made for the ferment in these cases is simply that there is absolute certainty of good results, and all of the common "errors" of butter making are avoided. In these experiments the cream is separated by the centrifugal machine, and being therefore fresh, Weigmann did not find it necessary to sterilize the cream before inoculation, since the number of bacteria in it was not excessively great. If it is to be adapted to the common method of separating cream in this country, the cream must be in some way deprived of most of its bacteria before inoculation.

Coming now to my own experiments, the first endeavor has been to study the normal ripening of cream in order to find out as much as possible in regard to the process as ordinarily conducted in our creameries. For this purpose a bacteriological study of ripening cream has been made at different seasons of the year. The cream which I have used for experiment has been mostly obtained from the Cromwell creamery. It has been taken from the cream vats, commonly when fully ripened, placed in sterilized test tubes and brought to the laboratory, through the kindness of Mr. Hammond, the superintendent. Besides the cream obtained from this source, specimens have been obtained from other dairies for comparison ; one specimen from Durham creamery, some from the private dairy at the Storrs School, and some has been ripened in the laboratory.

The cream thus received has been subjected to the ordinary bacteriological examination. As a culture medium, beef peptone gelatine has been used. Some experiments have been made with the use of a culture medium made from milk, but it has proved of no special advantage. With a drop of ripened cream, Esmarch tubes or gelatine plates have been made. The bacteria are so numerous that it is always necessary to make three tubes of successive dilution, even though only a small drop of the cream is put into the first one. The Esmarchs thus made are allowed to stand till the bacteria have formed colonies, and then all which give any indication of being separate varieties are fished out and inoculated into gelatine tubes. Then follows a purification of the species, which is accomplished by a series of cultures. Ordinarily two series of Esmarch tubes are sufficient to purify the cultures, though sometimes more are necessary. After the purification of the cultures their characters are studied in the ordinary manner, by a series of cultures in various media. Such a method of bacteriological study will not give all the varieties which are present in the cream, but will give all the rapidly growing ones, and these, of course, are the only ones that can have an important influence in a ripening process which is commonly not allowed to continue more than twenty-four hours.

NUMBER AND VARIETY OF BACTERIA.

First it will be well to notice a few facts in regard to the number of bacteria found in cream. Of course the number is subject to the wiedst variation with the temperature and the time of ripening. Actual numerical estimations have, therefore, very little value. Indeed, the number of bacteria is so great that no estimation can be made with anything like an approximation to accuracy. When the numbers reach 200,000 to 2,000,000, in a single drop of the size of a pin-head, as has been estimated in some of the specimens studied, it is plain that any numerical estimate ceases to have value. I have regarded it, therefore, as not worth the trouble to attempt numerical estimations, and have spent little time in this direction. It has been determined by many experiments that the number of bacteria in ripened cream is immensely greater than the number in sweet cream. The latter may have no more than are present in milk, while the ripened cream always has numbers far beyond any estimates of the numbers found in the worst milk. I have found a larger number of bacteria in centrifugal cream than in the skim milk taken at the same time. The slime that collects on the drum of the machine was found to have more than either the milk or the cream. This is the same result as was reached by Wyss [90], who stated that this slime contained seven times as many bacteria as the milk. I did not find so great a numerical difference.

One of the chief objects in this study has been to determine how great a variety there exists in the bacteria found in normally ripening cream, and to see if there is any one or any few species which are distinctly characteristic of the process. Examinations have therefore been made of the cream from the same dairy at different seasons of the year, and to a certain extent of specimens taken from different localities at the same time. The varieties of organisms thus found have been carefully studied, and descriptions of their characters made and preserved for comparison. In this way the bacteria of different seasons and different localities have been compared with each other. Of course such a series of experiments has been long and has required many hundreds of inoculations. It has resulted in the isolation of a large number of varieties of bacteria. It is evident that almost any saprophytic bacteria may get into milk and there grow, and these would appear in the cultures. At least fifty different species or varieties of organisms have been isolated and studied, including bacteria, yeasts, and moulds. Among them are many of the well-known forms described in bacteriological text-books, but a larger number of forms which do not agree with any description that I have been able to find. In calling the forms varieties, it is simply meant that they show different physiological characters. Most of the forms studied are bacilli, and many of them cannot be distinguished from each other by the microscope. Still their physiological properties differ in some respects, either in their action on milk, their growth in gelatine, or in the form of colony which they produce. Our whole knowledge of the significance of species and varieties among the bacteria is yet vague, and when mention is made of varieties we must simply mean varieties as shown by physiological effects. The experiments in collecting the forms of bacteria found in ripened cream are still in progress, and new varieties are being constantly found. I shall therefore reserve a special description of the individual species until it seems that a tolerably complete list of the common forms in cream can be given. It may be that a complete list can never be given, and that the forms are constantly undergoing modification. To determine this will of course require a long series of years. At the present time, at all events, the only statements of value which can be made are concerning the classes of physiological action shown by the various forms.

The experiments thus far have shown a great variety among the forms of bacteria which are prevalent in cream ripened even in the same creamery. In any given specimen of cream there will be found from ten to twenty different species of bacteria. From the same creamery, moreover, there will be wide differences in the successive specimens. In specimens of cream taken for some time at about two weeks' intervals, the same varieties of bacteria have in no case been found in successive lots. The differences are quite striking. One lot may contain a great majority of liquefying forms, and the next lot, from the same creamery, nearly all non-liquefying organisms. Of course there are some forms that are more or less constant and will be found in nearly all specimens for a long time. Others will occur only once, though they may be very abundant at that time. With such a difference in the specimens taken from the same creamery, it was not to be expected that cream from different dairies would have much similarity. Indeed, examinations of cream of the same date from different localities, has shown as wide differences, or even wider, than different specimens from the same creamery at different dates. Still there are some forms which have been found at all seasons, though not in all specimens.

From this great variety we must conclude that the special series of forms of bacteria which are present in any specimen of ripening cream is more or less a matter of accident. In the cream, there is a great battle of the forms with each other. The victors will be those which chance to get the best start, and this depends upon such a variety of circumstances connected with the collecting of the cream that it is entirely beyond our knowledge. No means at the command of the dairyman can regulate the bacteria supplied him by his customers, nor the variety which produce the ripening of his cream. Uniformity in the ripening process does not occur, even under seemingly uniform conditions.

ACTION OF BACTERIA ON MILK AND CREAM.

The next question to be asked is what effect these various bacteria have on cream during their growth. Culture experiments on cream are very unsatisfactory, owing to the difficulty of sterilizing cream without destroying its natural character. But as we have seen, the composition of cream is the same as that of milk, and therefore we can make a determination of the effects of the bacteria upon the cream by studying their growth in milk. Some experiments have been made upon the growth of bacteria in cream, but they have not been satisfactory, and have taught nothing beyond the readiness with which bacteria will grow in cream, and the fact that their general effect here is much the same as their effect on milk. Most of my experiments on this subject have therefore been confined to the study of the growth of bacteria in milk. The milk used for the purpose is sterilized by steaming for half an hour on three consecutive days.

Previous to the sterilization, a small amount of neutral litmus solution has been in some cases added to the milk in order to determine the reaction with ease.

The effect of the different varieties of bacteria upon milk are about as varied as the bacteria themselves. Still it is possible to divide them into three classes with tolerable exactness. The following classes have been recognized by Adametz [90], and my experiments to a certain extent have upheld such a classification.

The first class renders the milk acid, and the acid formed precipitates the casein of the milk. It was formerly supposed that a single species was concerned in this production of lactic acid, a species studied by Pasteur [57], and Lister [74], and subsequently described by Heuppe [84]. Subsequent work of Heuppe [85] and Marpann [86] and others has shown that a number of species can produce lactic acid, and lactic acid production is now recognized as a property of a large number of bacteria. In my work I have not yet found any form which agrees exactly with the *Bacillus acidi lactici* which was described by Heuppe. Several bacteria have been isolated which agree with it in most particulars, but in every case there has been some point of difference which has indicated that I have not had exactly the same form. The acid formed by the various members of this class is usually lactic acid, but acetic acid and formic acid have been found in some cases by Mr. Dains, who has made some chemical studies of my cultures. This class of bacteria usually do not liquefy gelatine, are commonly short bacilli, and do not form spores. Most of them are aerobic. The coagulation which they produce is usually distinguished with ease from that of the second class by its superficial characters. The curd is hard and has commonly a tendency to fragmentation. Frequently a little clear liquid separates from the curd, but there is never any tendency toward the solution of the curd. Of the species thus far isolated from cream, the larger number belong to this class.

The second class of bacteria curdles the milk without rendering it acid. The bacteria belonging to this class are all organisms which liquefy gelatine, and many of them produce spores. Butyric acid is one of the common by-products of the action on milk. The coagulation of this class of organisms can usually be distinguished from that of the first class by other features than the reaction. The curd formed is not hard and fragmented, but is soft and jelly-like, or sometimes divided into fine flakes. It is further found that after a few days the curd begins to grow less in amount and a whey to appear. As the growth continues longer, the curd is seen to be slowly dissolved, and this gradual solution may continue until the curd is completely dissolved into a limpid liquid. The solution may, however, in some species stop short of completion, and there may be thus formed a quantity of liquid, in which a small curd floats. The liquid formed differs widely in different cases. It is sometimes clear and sometimes cloudy. Sometimes it assumes an amber color, and in one case a brilliant yellow color was produced in the dissolved liquid. At other times the liquid becomes greenish.

There is very little reason to doubt that in the case of this second class of organisms the action on the milk is produced by the formation of soluble chemical ferments or *enzymes*. Duclaux [82], who first described this sort of growth, so explained it, and Heuppe [84] and others have followed him in the explanation. The ferment which produces the curdling is supposed to be similar or identical with the rennet ferment. The solution of the curd, however, is a different matter, and seems to be a process similar to pancreatic digestion. Peptones are nearly always found in the solution, and leucin and tyrosin among the nitrogen-holding extractives have frequently been detected, Lœffler [87] and Warrington [88]. In my own experiments, peptones have been detected, but no search has been made for leucin or tyrosin. It is supposed that this digestive action is caused by a second soluble ferment made by the bacteria, which is similar to trypsin. So far as I am aware, no one has actually succeeded in isolating the rennet-like ferment from the bacteria cultures, but several experimenters, Arloing [89], Baginsky [90], and others, have rendered it almost certain that enzymes are formed by bacteria. A chemical ferment which liquefies gelatine has been proven to be produced by some bacteria, and the liquefaction of gelatine is a process closely related to digestion of proteids. Beyerink [89], Brunton and MacFadyen [90], and Duclaux [87] have succeeded in separating the peptonizing ferment from certain bacterial cultures by means of precipitation with alcohol. To this ferment Duclaux gives the name of *casease*, and states that it acts upon casein in such a way as to turn it into a material, which he calls *caseone*, and which is more easily assimilated by the bacteria. The object of the solution is therefore primarily for the aid of the growth of bacteria. This action becomes one of great importance in the case of ripening cheese, Adametz [89].

That the curdling of milk and the subsequent solution of the curd are processes independent of each other, is indicated by the following observations of my own. It has been found that some species of bacteria have the one power without the other. Adametz [90] mentions some species which digest the casein of milk without previously curdling it. Among the species which I have isolated from cream, two have been especially interesting in this connection. The first is an organism growing into long rods, which occasionally branch and break up into short, oval, yeast-like bodies. It has many points of resemblance to *Sacharomyces albicans*. This species has a very characteristic growth on gelatine, forming a layer resembling ground glass, and is easily distinguished from any other organism which I have found. When first studied, it was found that at the ordinary temperature of the room it would not curdle the milk, but that it did slowly digest the casein. The milk became clear and transparent after a few days, appearing exactly like the peptonized curd of other species, but without the previous precipitation of the casein. When this species was grown in milk in a warm oven, at a temperature of about 35° C. the curdling appeared first, and the peptonizing subsequently took place. After several months of cultivation I found that this organism had lost its power of precipitating the casein. Even when growing in the warm oven the power of curdling the milk did not appear. The organism had, however, lost none of its morphological characters, and it still possessed the power of peptonizing the casein.

The second species is one of the forms of bacilli which would be included under the general name of *Bacillus fluorescens liquefaciens*. A number of liquefying forms seem to have the power of producing a fluorescent appearance in gelatine, and the above name probably includes several varieties. The variety which I have isolated and studied acted at first like ordinary liquefying organisms, curdling the milk rapidly and subsequently dissolving the curd. This organism was kept in the laboratory for several months and carried through a large number of cultures. After three or four months it was noticed that its power of curdling milk was becoming less marked, as it required a longer time or a higher temperature for this purpose. Finally it disappeared altogether. The digesting power was not lost however, for the milk was peptonized as usual.

In these two cases it is plain that we have an indication of the independence of the two actions on milk, and see that one may be lost without the other. We can hardly be wrong then in assuming, with all experimenters, that these liquefying organisms produce two chemical ferments, one having an action similar to rennet and the other an action similar to trypsin.

The third class of organisms which I would distinguish has no visible effect on milk. This does not mean that they have no effect, for they grow rapidly and produce various odors, indicating that decomposition changes are going on in the milk. The milk occasionally becomes slightly acid, sometimes slightly alkaline, or sometimes the reaction is not affected. In no case, however, is the acid sufficient to curdle the milk.

The distinction between these three classes of bacteria action is not sharp. The only difference between some of the third class and the first class seems to be in the amount of acid produced, in the one case enough being formed to precipitate the casein, and in the other case not a sufficient amount for this effect. Some of the peptonizing species moreover, produce a slight acid reaction. Usually the action in these cases is amphioteric or slightly alkaline, but a few of them render the milk acid, sometimes markedly acid, and in one case a very strong acid reaction was produced. In these cases the curd may be formed by the acid, and rennet ferment together. Lastly some species have been found which form a large amount of acid and precipitate the curd as a hard fragmented mass, like the first of the above classes, but at the same time they liquefy gelatine, digest the curd, and probably form a rennet-like ferment. It will be thus evident that the classes recognized by Adametz and others are not sharply distinct.

The production of an acid reaction in milk seemed, in all cases studied, to be due to the breaking up of milk sugar, as is shown by the following experiments. I have cultivated each bacteria variety in two bouillon solutions, one of which was an ordinary beef peptone solution, while the other was the same with the addition of a little milk sugar or glucose. The former solutions always became alkaline under the influence of the bacteria growth while the sugar containing bouillons were variously affected. Bacteria which turn milk alkaline also turned the sugar bouillon solutions alkaline without exception. Those which rendered the milk acid also turned the sugar bouillon solutions acid, with one, as yet unexplained, exception. Species of bacteria which did not affect the reaction of milk, were variable in regard to their effect on the sugar bouillon solutions. My experiments further show that it is easier for bacteria to produce acid from glucose than from milk sugar.

The production of an acid from milk sugar seems thus to be quite a common property of bacteria. It is possessed to a very varying degree, however. In some cases not enough acid is formed to curdle the milk, while in others the acid precipitates the casein quickly. Among the liquefying organisms, some produce acid, others do not, and where the acid is produced we cannot tell whether it is the acid or a rennet-like ferment that precipitates the curd.

One of the most striking results of the growth of different bacteria in milk is the character of the odors of the decompositions which are produced. This subject is, however, too intangible to describe. We have no names sufficient to enable us to classify odors, nor have we sufficiently well trained senses of smell to enable us to remember a new odor for a long time. It is certain that the odors produced in the different milk cultures are widely varied and give plain indication of the formation of numerous volatile products, but I have been entirely unable to classify them. These odors are important factors in producing the aroma of the butter which is made from the ripened cream. If it were possible to develop the discrimination of this sense of smell, and to create a language to go with it, it is likely that a new and important factor could be added to bacteriological investigations.

After thus considering the great variety among the forms of bacteria found in ripened cream, the question is naturally asked whether there is any one species, or any few species, which are so commonly present as to deserve to be called characteristic species of ripening cream. Thus far it has been impossible to answer this question in the affirmative, all indications seeming to point toward the negative conclusion. It is a fact, however, that in all specimens of ripened cream examined, there were large numbers of the lactic acid forming species, and these are, of course, the essential factors in the souring of cream. The peptonizing species, though almost always found, are by no means so universally present in abundance. As regards single species, some have been found to occur very commonly in many specimens of cream, but I have not been able to find any which can be regarded as a characteristic species. It is certain that no one species can be regarded as especially characteristic of the process of ripening.

It will be seen that the physiological action of the bacteria as above outlined will explain all of the characters of ripened cream. The souring is due, of course, to the formation of lactic acid by the acid-forming class of organisms. The slight thickening is due to a more or less complete precipitation of the casein in the form of a curd. The odor is due to a mixture of the volatile products of bacteria growth. The peculiar aroma so important to the butter is due to the same cause. The greater ease of churning sour cream is readily explained by the fact that either the acid formed by the bacteria, or the trypsin-like ferment, or both, will tend to dissolve the proteid mass (fibrin?) which we have seen holds the fat globules together. As soon as this fibrous mass is broken down, the globules can more readily be shaken together so as to fuse into large granules.

Having reached this position, it becomes desirable to study the effect upon butter of ripening the cream with different species of bacteria. If the right species may be found to be used as an artificial ferment for the ripening process, this process may be controlled, and if it can be controlled, the irregularities of butter making may be eliminated. Experiments in this direction have been begun in connection with the dairy of the Experiment Station, but the work has not advanced far enough at the present time to give any definite results.

SUMMARY.

The most important points brought out in the present article are the following:

The ripening of cream is a process produced by bacteria growth. This is shown by the immense number of bacteria in the cream, and their almost incredible multiplication during the ripening process, and by the fact that all conditions which hasten bacteria growth also hasten the ripening process.

The variety of bacteria which are found growing rapidly in ripening cream is very great, and there is no uniformity in regard to species. Hardly two specimens of cream in the same creamery are ripened by the same variety of bacteria. The conditions affecting the growth of different species of bacteria are entirely beyond the control of the butter maker, and it is impossible to obtain uniformity of results by the ordinary methods of ripening. This fact is doubtless the cause of the occurrence of butter of inferior quality at certain seasons, and is one of the causes of difference between the butter of different creameries and dairies.

The bacteria which ordinarily ripen cream produce three classes of effects upon it during their growth. Some of them produce lactic acid, or small quantities of other acids. Some of them produce a rennet-like ferment which tends to precipitate the casein, and also a trypsin-like ferment which digests or peptonizes the proteid matters present. Some of them produce no effect beyond a slight decomposition and the possible evolution of volatile products. All of them assist in giving the peculiar flavor to the cream, and therefore probably the aroma to the butter. Perhaps a satisfactory aroma can be obtained by the use of single species if carefully selected.

No especially characteristic species have been found connected with the ripening process. The acid-forming species are, however, the most uniformly present in great numbers, and these are probably the most intimately associated with the ripening.

A MICROCOCCUS OF BITTER MILK.

BY

H. W. CONN, PH. D.

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In the course of my experiments on cream, one species of bacteria has been isolated which is so peculiar in its characters as to deserve special mention. A specimen of cream was sent to me from the Experiment Station, in November, which had a decidedly bitter taste. By bacteriological examination, I succeeded in isolating from it nine varieties of bacteria, one of which was found by subsequent experiments to be the cause of the bitter taste.

It has been commonly supposed that the formation of a bitter taste in milk was connected with the formation of butyric acid. The butyric acid fermentation as studied by Duclaux [82], Prazmosky [80], Fitz [82], Pasteur [60], Lœffler [87] and others, is almost always accompanied by a bitter taste. Quite naturally, therefore, the bitter taste which it sometimes developed spontaneously in milk has been connected with the same class of organisms. Recently, however, Weigmann [90] has concluded that the butyric acid has no necessary connection with the bitter taste. Butyric acid in itself is not bitter. Weigmann finds the bitter taste produced by a special bacillus which he isolated from bitter milk. This organism has no power of curdling milk, bût does digest the casein. By chemical examination of milk in which it had been growing, Weigmann determined that no butyric acid is formed. He made a study of several other somewhat similar bacteria, but found none which had a similar effect of rendering milk bitter.

The organism which I have found in the specimen of bitter cream is undoubtedly a different one from that found by Weigmann. The following is a description of its characters:

Morphology—It is a good-sized micrococcus which has no tendency to form chains. Occasionally two may cling together, producing diplococci. This is especially the case in gelatine and milk cultures. In agar it becomes longer, and rods are found several times as long as broad, which I have not been able to break up into cocci.

Mobility—Not mobile.

Relation to the Air—Aerobic—Under a mica plate it grows very slowly, giving rise to bubbles of gas, and the liquefaction of the gelatine takes place slowly. No such bubbles are produced where the plate is not covered with mica, and liquefaction is rapid.

Color—White.

Colony on Gelatine—Under the surface the colony is smooth and round. As it approaches the surface it becomes almost immediately diffused over the gelatine into a fine, thin granular mass, which spreads rapidly. There is no definite shape to the colonies after this.

Gelatine Stab Culture—At first a very shallow pit is formed, but this spreads into a uniform layer of liquefying gelatine, which slowly deepens until the whole is liquefied. The resulting liquid is very slimy.

Agar-Agar—A white glistening uniform growth.

Potato—A white mass of more or less discrete bunches, glistening and moist; color of the potato not changed.

Milk—Curdled in one day in a warm oven. Becomes very bitter. The litmus solution which is added to the milk turns slightly red. Later the color of the litmus is bleached. The curd which is formed soon begins to dissolve, though the solution is never quite complete. The liquid thus formed is slimy.

Bouillon—Growth abundant. A thin membrane forms on the surface. The bouillon becomes remarkably slimy, and can be drawn out into threads ten feet long. Odor and taste like that of bitter milk.

The most remarkable feature of this organism is the power of rendering bouillon and gelatine slimy. The tenacity of the slime is hardly credible. The mass can be sometimes drawn out into threads ten feet long and no larger than a thread of silk, so as to be hardly visible. Curiously enough, though both bouillon and gelatine are thus rendered slimy, the sliminess does not at first appear in milk. After the digestion of the curd has taken place the liquid becomes slimy, but no slimy milk proper is formed; so this organism is therefore not one of those which produce the well-known slimy milk.

The taste produced in the milk is extremely bitter. It is not exactly like that of the original bitter cream from which the organism was obtained. This is due, however, to the fact that other organisms were present in the cream. I found that if a lot of sterilized milk was inoculated with the bitter organism and at the same time with one of the lactic acid forming species, the taste is almost exactly that of the original cream.

This organism undoubtedly produced a chemical ferment or enzyme, with action similar to that of rennet. This was shown by the following experiment. The organism was grown in a bouillon solution for a couple of days. A considerable quantity of this liquid was poured into a tube of sterilized milk, and at the same time chloroform was added to the milk to prevent the bacteria growth. The milk placed in an oven was curdled in less than an hour. Since no bacteria growth ever produces curdling in so short a time, and since, moreover, the presence of chloroform prevents the bacteria growth, there is no question that in this case a chemical ferment must have been present in solution. I have not yet isolated the ferment.

By the following experiment, performed with the help of Prof. Phelps, the effect of this organism in the ripening of cream was determined. The organism was cultivated in a flask of sterilized milk in a warm oven until a rich culture was obtained. A lot of cream collected at the Experiment Station was divided into two parts. One lot was ripened in the ordinary manner by simply placing it in a warm place for forty-eight hours. The other half was first heated to a temperature of 70°C. for half an hour, to destroy most of the bacteria present in it. Then it was inoculated with the milk culture of the bitter organisms above mentioned. The two lots of cream were subsequently placed side by side and treated in the same manner. The test cream soon curdled and acquired a bitter taste, while the control did not curdle and simply became slightly acid. Each was churned after standing forty-eight hours. The test butter obtained was remarkably inferior to that of the control cream. The latter was a fair quality of winter butter. The test butter had a slightly rancid odor and taste, and had a very bad flavor. It leaves a strong burning taste on the back of the tongue, which could be perceived for half an hour after the butter was swallowed. The butter was in short not fit to use. Samples of the test butter and of the control butter were salted and were preserved to determine the keeping qualities. In two days the test butter was strongly rancid, and the taste was strong and burning. The control butter was only slightly changed.

In this experiment so much of the test culture was added to the cream that it became ripened sooner than the control. Thinking that the test might have ripened too long, we repeated the experiment after an interval of four weeks. Care was taken this time not to allow the test to become too ripe. Very little difference in the result was seen. The strong rancid taste, with the noticeable burning sensation, were about as strongly marked as in the first experiment. In the last example the amount of butter obtained from the test was about one-fourth less than that obtained from the control. These experiments were performed in January and February.

Mr. Dains, a graduate student of Wesleyan University, has made an examination of the milk culture of this organism for the purpose of determining whether butyric acid is formed. The milk was first filtered, and the filtrate distilled with a little phosphoric acid. The distilate was slightly acid, and had a noticeable odor. It was neutralized with NaOH and evaporated to dryness. Further treatment with sulphuric acid and alcohol gave a prominent odor of bananas, thus indicating the presence of butyric acid.

From these experiments it is plain that the bitter organism thus described is one which will prove an injury to butter, and must be avoided in all attempts to obtain first quality butter. Of course the effect obtained by ripening the cream with the pure culture is an exaggerated one, and in ordinary ripening these bad effects will be partly offset by the other organisms present. But this shows what the organism will do in cream, and where it is present it will, of course, produce its effect though in less degree. First quality butter cannot be made if this organism is present in the ripening cream.

REFERENCES.

The numbers after the names of authors in the body of the text refer to the numbers given below, and give in each case the year in which the article in question was published.

Adametz [89], Berlin Land. Jahr, 1889.
" [90], Oetserreich. Monats. f. Thierheilkunde, 1890.
Arloing [89], Comptes Rendues, 1889, p. 842.
Ascherson [40], Arch. f. Anat. and Path., 1840.
Babcock [86], Bull. of N. Y. Exp. Sta., 1886.
" [89], Bull of Wis. Exp. Sta., No. 18.
Bechamp. [88], Comptes Rendues, 1888, p. 272.
Baginsky [90], Zeit. f. Phys. Chem., Vol. XII.
Beyerink [89] Cent. f. Bact. u. Par,, 1889.
Bouchardat & Quevenne [57], Le Lait, 1857.
Brucke [47], Müller's Arch., 1847, p. 409,
Brunton & Macfadyen [89], Proc. of Roy. Soc., 1889.
DeSinty [74], Arch. f. Phys., 1874.
Donne [44], Cours d. Microscopie, 1844.
Duclaux [82], Ann. d. l'Inst. Nat. Agron, Paris, 1882.
" [88], Le Lait, 1888.

Fitz [82], Ber. d. d. Chem. ges, 1882.
Furstenburg [68], Die Milchdrusen der Kuh, Leipzig, 1868.
Haidenhain [80], Article on Milk in Hermann's Handbook.
Hammersten [74], Jahr. d. Thierchemie, 1874.
Heintz [53], An. d. Chem. u. Pharm., 1853. p. 300.
Henle [39], Froriep's Notizen, 1839.
Hoppe. [59], Virchow's Arch., Vol. XVII., p. 417.
Heuppe [84], Mith. a. d. Ges. Amt., 1884.
" [84], Deut. Med. Woch., 1884.
Kehrer [71], Arch. f. Gyn., 1871.
Kühne, [68], Physiologisches Chemie., Leipzig, 1868.
Lehman [50], Physiologisches Chemie., 1850.
Lister [74], Quar. Jour. Mic. Sci., 1874.
Lœffler [87], Ber. Klin. Woch., 1887.
Marpman [86], Cent. f. Allg. Gesund., 1886.
Martiny [71], Die Milch., p. 84, 1871.
Molleschott [52], Arch. f. Phys. Heil., 1852.
Meyers [90], Bull. of W. Va. Exp. Sta., No. 6, 1890.
Pasteur [57] Comptes Rendues, 1857.
" [60], " " 1860.
Prazmosky [80], Untersuch. ub. d. Ent. u. Fermentwirkungen einigen bac., Liepzig, 1880.
Schwalbe. [72], Arch. f. Mic. Anat.. 1872.
Simon [40], Handbuch d. an. gewand. med. Chem., 1840.
Storch. [77], Fühling's land. Zeit, 1877.
" [90], Milchzeitung, 1890.
Soxhlet. [42], Jour. f. prac. Chem., 1842.
" [76], Land. Vers. Stat., 1876.
Turpin [37] Comptes Rendues, 1837, p. 822.
Warrington [88], Jour. of Chem. Soc,, 1888.
Weigmann-Kiel [90], Milchzeitung, 1890.
Wittich. De Hymenogonia Albuminis. Year not given
Wyss [90], Tagbl. d. 62 Versam. Deut., 1890.
Zahn. [66] Arch. d. d. ges. Phys., 1866.

ON THE SCHULZE-TIEMANN METHOD OF ESTIMATING NITRIC ACID.

BY

H. B. GIBSON.

Among the sources of error incident to the determination of nitric acid by the Schulze-Tiemann method, the following may be mentioned:

1. Air incompletely expelled from the flask in the preliminary boiling, or admitted with or contained in the reagents added.
2. Nitric oxide (NO) incompletely expelled from the flask.
3. Formation of nitrous oxide and nitrogen gas as by-products.*
4. Incomplete reaction between ferrous chloride, hydrochloric acid, and nitrates.
5. Absorption of nitric oxide by caustic soda solution, over which it is collected.
6. In the use of the modified Schiff azotometer,† difference of temperature between the nitric oxide and the surrounding water-bath.

The object of this article is to present observations which bear directly on the last three sources of error, and which will be discussed in order.

I. REAGENTS AND MANIPULATION.

In the use of the Schulze-Tiemann method for the determination of nitric acid, careless manipulation or the use of poor reagents may give low results. These low results may be due to an incomplete or even to a slow reaction between the nitrates whose nitrogen is to be determined as nitric oxide, and the ferrous chloride in the presence of which this gas is liberated. That tardiness of reaction which results in the evolution of nitric oxide in small bubbles may become a source of error, will be seen under the subject of "Absorption," beyond. According to our experience, the errors arising from such defective manipulation may be avoided by taking the following precautions: (1) Boil the solution of nitrates to within at least 2 cc. of dryness; then (2) add 20 cc. of a saturated solution of freshly reduced ferrous chloride, and about 15 cc. of concentrated hydrochloric acid, and then (3) let the contents of the flask digest for at least ten minutes in the cold, and then apply heat gradually so as to prevent bumping. This digestion gives time for the reaction between the ferrous chloride and nitrate to begin, and thus insures a rapid and uninterrupted flow of gas when heat is applied.

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* Russell and Lamprach, J. C. S., 1887, II., 36.

† On the Determination of Nitrogen, by S. W. Johnson and E. H. Jenkins. American Chemical Journal, II., 27.

2. ABSORPTION OF NITRIC OXIDE.

When nitric oxide is collected over a ten per cent. solution of caustic soda and the eudiometer then immersed in water in the ordinary manner,* the results, even if constant, are apt to be low, and there is absorption of the gas after the diffusion of the water and caustic soda is complete. To remedy this error, a modified Schiff azotometer may be substituted for the eudiometer ordinarily employed, and a saturated solution of caustic soda for the ten per cent. solution.

Tables 48 and 49, which follow, give the results of two series of determinations made with the Schiff azotometer as modified by Johnson and Jenkins, at different ranges of temperature, with special reference to the amount of absorption of nitric oxide which may take place when this gas is collected over and allowed to stand in contact with various mediums. The substance used for each determination was .25 gram of potassium nitrate, containing theoretically 13.85 per cent of nitrogen. The aqueous solution of potassium nitrate was evaporated and the reagents added as above described, and after ten minutes' digestion the gas was collected in an azotometer over the medium whose absorptive capacity for nitric oxide was to be tested. When the gas had ceased to come off in bubbles larger than a pin's head the determination was deemed finished, and the volume, temperature, and pressure were noted at once, and also after intervals of 5, 10, 15 and 30 minutes, and 1 hour, 2 hours, etc. The value of the volume of nitric oxide, reduced to 0° and 760 mm. and calculated into milligrams of nitrogen is given, the results being placed opposite the time in minutes or hours at the end of which the respective readings were made. Each column represents the change in amount of the nitric oxide (in milligrams of nitrogen) which was given off from the quarter gram of nitrate used in each determination, on standing over the medium specified. For example: In column 1, under Water, the value of the volume of nitric oxide at the end of the evolution of gas was 33.2 mgs. of nitrogen; 5 minutes later, 33.2 mgs. of nitrogen; 1 hour later, 33.1 mgs. of nitrogen, etc.

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* Fresenius' Quantitative Analysis, Second American Edition, page 473.

TABLE 48.

Showing Absorption of Nitric Oxide on Standing over Water, 10 Per Cent. Caustic Soda Solution, and Saturated Caustic Soda Solution. Results in Milligrams of Nitrogen found.

TIME BETWEEN THE END OF THE REACTION AND THE READING.	OVER WATER.			OVER 10 % CAUSTIC SODA.				OVER SATURATED SODA.		
	Temp., 7°—10°. Bar., 763—764 mm.			Temp., 6°—15°. Bar., 756—763 mm.				Temp., 6°—13°. Bar., 740—754 mm.		
	1	2	3	1	2	3	4	1	2	3
	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.
0 minutes,	33.2	33.7	34.1	33.8	34.0	34.0	34.0	34.5	34.5	34.4
5 "	**33.2**	**33.5**	**34.0**	**33.8**	**33.9**	**34.0**	**34.0**	**34.5**	**34.4**	**34.3**
10 "	33.2	33.7	34.1	33.6	33.9	33.9	33.9	34.4	34.3	34.2
15 "	33.1	33.7	34.0	33.6	33.8	33.8	33.9	34.3	34.2	34.2
30 "	33.1	33.6	34.1	33.6	33.9	33.9	34.0	34.2	34.1	34.1
45 "	33.1	—	—	33.7	33.9	33.9	33.9	34.1	34.1	34.1
1 hour,	33.1	33.5	33.9	33.7	33.9	33.8	33.8	34.2	—	34.1
2 hours,	33.2	33.5	33.9	33.7	33.8	33.9	33.8	34.1	—	34.0
3 "	—	33.4	—	—	—	—	33.8	34.1	—	34.1
4 "	33.2	—	33.9	33.6	—	33.9	—	—	—	—
5 "	—	—	34.0	—	33.8	33.9	33.8	34.0	—	34.0
6 "	—	—	33.9	—	—	—	—	34.0	34.0	33.9
7 "	—	—	33.9	33.6	—	—	—	—	—	—
8 "	—	—	—	—	33.6	—	—	—	—	—
24 "	—	—	—	33.3	33.5	—	—	33.8	—	—

TABLE 49.

Showing Absorption of Nitric Oxide on Standing over Water, 10 Per Cent. Caustic Soda Solution, and Saturated Caustic Soda Solution. Results in Milligrams of Nitrogen found.

TIME BETWEEN END OF THE REACTION AND THE READING.	OVER WATER.				OVER 10 % CAUSTIC SODA.				OVER SATURATED SODA.			
	Temp., 15°—19°. Bar., 755—766 mm.				Temp., 15°—19°. Bar., 749—758 mm.				Temp., 14°—21°. Bar., 746—757 mm.			
	1	2	3	4	1	2	3	4	1	2	3	4
	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.
0 minutes, - - - - - - -	34.2	**34.5**	34.2	33.7	34.8	34.8	34.6	34.5	34.9	34.7	34.8	**34.6**
5 " - - - - - - -	**34.1**	—	**34.3**	**33.7**	**34.5**	**34.8**	**34.4**	**34.5**	**34.7**	**34.5**	**34.6**	—
10 " - - - - - - -	33.9	—	34.3	33.7	34.5	34.7	34.4	34.4	34.8	34.3	—	34.4
15 " - - - - - - -	33.9	—	34.2	33.7	34.4	34.7	—	34.3	34.7	34.3	34.3	34.3
30 " - - - - - - -	34.0	34.5	—	33.7	34.5	34.6	34.4	34.3	34.7	34.3	34.3	34.3
45 " - - - - - - -	—	—	34.2	—	34.4	34.7	—	—	34.5	34.3	34.3	34.3
1 hour, - - - - - - -	34.0	34.4	34.2	33.7	34.3	34.6	34.2	34.3	34.6	34.2	34.3	—
2 hours, - - - - - - -	34.0	34.5	34.2	—	34.3	34.6	34.2	34.3	34.6	34.2	34.3	34.4
3 " - - - - - - -	34.0	—	—	—	34.3	34.5	34.3	34.3	34.6	—	34.1	34.2
4 " - - - - - - -	—	34.5	—	33.6	34.4	34.5	34.1	34.3	—	34.1	34.1	34.2
5 " - - - - - - -	34.0	34.5	—	33.6	—	34.1	34.2	34.4	34.5	—	34.2	34.1
6 " - - - - - - -	—	—	—	—	—	34.1	34.0	—	34.5	34.1	34.2	34.2
7 " - - - - - - -	33.9	—	—	35.7	—	—	—	34.3	34.4	34.2	—	—
8 " - - - - - - -	—	34.5	—	—	—	34.0	—	—	34.5	34.1	34.3	34.3
9 " - - - - - - -	33.9	—	—	—	—	—	—	—	—	—	—	—

From Table 48.

Percentages of Nitrogen Found.

Over Water. Temperature,	10°	9°	8°	—	Av.
Percentage,	13.28	13.42	13.59	—	**13.43**

Over 10 % Caustic Soda. Temperature,	9°	7°	14°	8°	Av.
Percentage,	13.52	13.56	13.59	13.59	**13.57**

Over Saturated Caustic Soda. Temperature,	10°	9°	10°	—	Av.
Percentage,	13.79	13.71	13.72	—	**13.74**

From Table 49.

Percentages of Nitrogen Found.

Over Water. Temperature,	16°	17°	17°	16°	Av.
Percentage,	13.65	13.79	13.72	13.46	**13.66**

Over 10 % Caustic Soda. Temperature,	15°	16°	16°	16°	Av.
Percentage,	13.81	13.92	13.77	13.78	**13.82**

Over Saturated Caustic Soda. Temperature,	19°	16°	15°	17°	Av.
Percentage,	13.90	13.80	13.82	13.82	**13.84**

The absorption on standing in contact with the various mediums is comparatively small, and may be stated as follows: Over water, very little or none at all, either at the lower or higher ranges of temperature; over 10 per cent. soda solution, a more marked absorption through both ranges of temperature than over water; and over a saturated solution of soda, a relatively large amount of absorption at both high and low temperatures. However, absorption may take place not only on standing over the absorbing medium, but also while passing through it, and it is here that the main danger from absorption lies. This may be seen from the percentage values of the numbers in full-face type in tables 48 and 49, the readings having been made after 5 minutes' standing, given on the preceding page.

From these results it may be inferred that the absorption of nitric oxide in passing through water at temperatures from 9°–17° is relatively large, and in passing through a 10 per cent. solution of caustic soda considerable at winter and little or none at spring or summer temperatures, and that a saturated soda solution from 9°–19° absorbs practically no nitric oxide during the passage of the gas. If, however, the reaction between the nitrates and ferrous chloride is tardy, and the nitric oxide is given off in small bubbles (see page 163) thereby exposing the gas more thoroughly to the absorptive action of the caustic soda solution than if the bubbles were larger, it does not seem improbable that part of the absorption which occurs on standing, may take place during the passage of the gas, even if collected over a saturated soda solution, and thus materially lessen the volume before the readings are made.

As a result of several trials in which the nitric oxide had been evolved rapidly and passed in large bubbles through the caustic soda solution, no traces of hydrochloric acid were found when the freshly collected gas was immediately made to bubble through a solution of silver nitrate. Even when water, instead of a solution of caustic soda, was used in the eudiometer of the azotometer, the gas failed to give any trace of hydrochloric acid. It is thus evident that even rapid manipulation did not introduce hydrochloric acid into the gas to be measured, and that the loss of volume was due to the absorption of nitric oxide, and not of hydrochloric acid which might have been carried past the caustic soda solution.

In the three determinations in table 48 in which water was used, the gas in the several successive trials was collected over the same water, while in table 49 the water was changed during the series. It will be seen that in the first series there is a gradual increase in the percentages of nitrogen found, from determination to determination, while in the second no such regularity can be observed. To ascertain if this gradual increase was accidental or due to the saturation of the water by the gas, so that in the later determinations less was absorbed than in the first, the gas in four consecutive determinations was collected over the same water, and the readings made at different times. The numbers 1, 2, 3 and 4 represent the order of the four consecutive determinations.

A Series of Consecutive Determinations in which the Nitric Oxide was collected over Water. Results given in Milligrams of Nitrogen.

TIME.	1	2	3	4	TIME.	1	2	3	4
	Mg.	Mg.	Mg.	Mg.		Mg.	Mg.	Mg.	Mg.
0 mts.,	33.7	34.2	34.5	34.8	45 mts.,	33.6	34.1	34.3	—
5 "	**33.6**	**34.1**	**34.5**	**34.7**	1 hour,	—	34.0	34.3	—
10 "	33.6	34.1	34.4	34.7	2 hours,	33.6	34.0	—	—
15 "	33.6	34.1	34.4	34.5	3 "	—	—	—	34.5
30 "	33.6	34.0	34.3	34.5	4 "	33.6	34.1	—	—

Calculated to percentages of nitrogen, the results of the readings at the end of five minutes are as follows:—

Number, - - - - - - - -	1	2	3	4
Temperature, - - - - - - -	23°	23°	22°	22°
Per Cent. of Nitrogen, - - - - -	13.43	13.64	13.81	13.86

The question might arise as to whether the absorption of gas in the earlier of these determinations which does not appear in the later ones, might not have been that of hydrochloric acid and not of nitric oxide, and a fifth trial was made and the gas immediately passed through a solution of silver nitrate, but there was not the slightest opalescence in the solution. In order to give confirmatory evidence to this trial and to those recorded on page 168, the following determinations were made under ordinary conditions of temperature and pressure.

Two Series of Consecutive Determinations in which the Nitric Oxide was collected over a 10 per cent. Solution of Hydrochloric Acid. Results in Percentages of Nitrogen in Potassium Nitrate.

SERIES 1.				SERIES 2.				
No.	1	2	3	No.	1	2	3	4
% of Nitg'n.	13.53	13.74	13.76	% of Nitg'n.	13.55	13.73	13.75	13.73

That the presence of hydrochloric acid in the water through which the gas was passed, and over which it was collected, checked the absorption of nitric oxide, in the manner in which a caustic soda solution does, is not indicated here; but confirmatory evidence is given to the statement made on page 168, that no hydrochloric acid is carried over with the nitric oxide. If this were the case, higher results might have been expected here, but on the contrary they were almost as low as when the gas was collected over water.

Three Series of Consecutive Determinations in which the Nitric Oxide was collected over Water, through which had previously been passed the Nitric Oxide from One Gram of Potassium Nitrate. Results in Percentages of Nitrogen in Potassium Nitrate.

Series 1.				Series 2.				Series 3.			
No.	1	2	3	No.	1	2	3	No.	1	2	3
% of N.	13.90	13.70	13.70	% of N.	13.87	13.73	13.73	% of N.	13.95	13.89	13.80

The high results of the first determination of each series may perhaps be accounted for by the supposition that some of the gas previously absorbed by the solution was set free, but this does not seem to be borne out by the following three series.

Three Series of Consecutive Determinations in which the Nitric Oxide was collected over a 10 per cent. Solution of Hydrochloric Acid, through which the Nitric Oxide from One Gram of Potassium Nitrate had previously been passed. Results in Percentages of Nitrogen in Potassium Nitrate.

Series 1.			Series 2.			Series 3.		
No.	1	2	No.	1	2	No.	1	2
% of N.	13.82	13.78	% of N.	13.72	13.77	% of N.	13.71	13.71

At first thought it would seem natural to suppose that if, as tables 48 and 49 show, there is very little absorption of nitric oxide on standing over water, there would be no harm in the use of the ordinary method of immersing the eudiometer in water in a large receptacle, and thus letting the gas stand in contact with the water. However, there is this difference: in the modified Schiff azotometer, the gas is in reality not over water, but over an aqueous solution of nitric oxide, whose capacity for further absorption is limited or quite gone, while in standing over the water in a large receptacle in which there is opportunity for diffusion, the gas comes to be in contact with practically pure water, or in the condition of bubbles of gas passing through the unsaturated water within the azotometer, where the greatest absorption occurs.

If the modified Schiff azotometer with a saturated solution of caustic soda is used, and the volume, temperature, and pressure are read at the end of five minutes after the evolution of gas has ceased, the error of absorption incurred may be safely neglected. The time, five minutes after the end of the determination, at which the readings are made is, of course, an arbitrary one, but it very well serves the purpose of giving the different parts of the azotometer time to come to a comparative equilibrium of temperature, and also makes all results comparable. Since the sodium hydroxide of the caustic soda solution is gradually changed by the hydrochloric acid into chloride, the solution should occasionally be renewed. When there is doubt as to the accuracy of results, it is desirable to confirm the method by trial with a known amount of nitrate.

3. DIFFERENCES BETWEEN TEMPERATURES OF GAS INSIDE, AND WATER OUTSIDE THE EUDIOMETER.

In the use of the modified Schiff azotometer the temperature of the nitric oxide is assumed to be the same as that of the water of the surrounding jacket. It might seem that an error would be introduced on account of this assumption, and in order to discover if this error existed, recourse was had to the following device. A thermometer registering the same as the one used in the water jacket was suspended in the eudiometer of the azotometer. In this way any changes which might take place in the temperature of the nitric oxide as well as in that of the surrounding water of the jacket could be easily detected. The results of seven determinations in which the temperatures of both the nitric oxide and the water of the jacket at several intervals of five minutes each after the evolution of gas had ceased, follow. The differences between the temperatures of the gas and the water—that of the gas being higher—are given. No change of temperature due to evaporation from the surface of the thermometer within the eudiometer could be detected. The volume of nitric oxide was approximately 51 cc. corrected for the displacement of the thermometer.

NUMBER OF DETERMINATION.	0 Minutes.	5 Minutes.	10 Minutes.	15 Minutes.	Temperature.
1 - - - - - - -	1.0	2.0	1.0	1.0	17°
2 - - - - - - -	1.5	2.0	1.0	1.0	17°
3 - - - - - - -	2.0	1.5	2.0	0.0	13°
4 - - - - - - .	1.0	1.5	0.0	0.0	13°
5 - - - - - - -	1.0	1.5	0.0	0.0	13°
6 - - - - - - -	1.0	1.5	1.0	0.0	13°
7 - - - - - - -	1.0	1.0	0.5	0.0	12°
Average, - - - - -	1.2	1.6	0.8	0.3	14°

In the last two trials, 6 and 7, the volume of gas was noted, and the amount of nitrogen at the various intervals of five minutes was calculated to milligrams of nitrogen, using both the temperature of the jacket and that of the gas itself in the reduction. In this way two sets of results, one corresponding to the temperature of the nitric oxide as indicated by the thermometer of the water jacket and the other to the actual temperature of the gas, were obtained. These results in milligrams of nitrogen appear below. The temperature of the water jacket is indicated by t, and that of the nitric oxide by t′. The volume is corrected for displacement of the thermometer.

TIME.	Vol.	t.	t′.	N. at t.	N. at t′
	cc.			Mg.	Mg.
0 - - - - - - -	51.35	13°	14°	30.47	30.33
5 - - - - - - -	51.05	12°	13°	30.42	30.29
12 - - - - - - -	50.70	12°	13°	30.21	30.08
16 - - - - - - -	50.55	12°	12°	30.12	30.12

TIME.	Vol.	t.	t′.	N. at t.	N. at t′
	cc.			Mg.	Mg.
0 - - - - - - -	51.45	12°	13°	30.66	30.53
5 - - - - - - -	51.15	12°	13°	30.48	30.35
10 - - - - - - -	50.90	12°	12°	30.33	30.33

The mean difference between the results of columns " N. at t," and " N. at t′," at the end of five minutes, is .13 mg. of nitrogen, or in this case an error of about one part in 230, which for all practical purposes may be neglected.

SUMMARY.

1. Manipulation and Reagents.

Care should be taken to concentrate the solution of nitrates as much as possible before adding reagents. The reagents should be added in a very concentrated form, and the mixture allowed to digest well before heat is applied.

2. Absorption.

In passing nitric oxide through solutions of caustic soda of various degrees of saturation, a saturated solution absorbs the least, but on standing over the same solutions it absorbs the most. In the use of the modified Schiff azotometer with a saturated solution of caustic soda most of the absorption is obviated.

That there is no hydrochloric acid gas carried over with the nitric oxide is highly probable, both from the fact that its presence is not detected by solutions of silver nitrate, and that the results obtained by collecting the gas over 10 per cent. hydrochloric acid are lower than when the gas is collected over a saturated soda solution, and do not differ greatly from those obtained by collecting it over water.

3. Variation of temperature.

Variations of temperature between the nitric oxide and the surrounding water of the water jacket are so slight that they may safely be neglected.

In a word, the greatest errors in the use of the Schulze-Tiemann method for estimation of nitric acid arise rather from careless manipulation or poor reagents than from absorption of nitric oxide when collected over a saturated solution of caustic soda, or from differences of temperature which occur when the temperature of the gas is assumed to be the same as that of the water surrounding the eudiometer of the azotometer.

THE FUEL VALUE OF FEEDING STUFFS.

BY

W. O. ATWATER.

It is now a little over thirty years since the experiments were undertaken by Bischof and Voit in Munich, Henneberg and Stohmann in Weende, Wolff in Hohenheim, and other German investigators, which have led to our present theory of nutrition and methods of estimating the nutritive values of feeding stuffs and planning rations for domestic animals on the basis of the quantities of protein, fats, and carbohydrates. The feeding standards of Wolff, now generally current, have been in vogue for somewhat over twenty years. It is, however, only seventeen years since the first exposition of the subject was made in the English language,* so far as the writer is aware, and it is less than fourteen years since the details were made available to students and practical farmers in the United States; yet such is the readiness with which new ideas are received and put to use in this country that for the past ten years the German feeding standards have been in common use in the United States and the method of calculating rations for domestic animals on the basis of the chemical composition of feeding stuffs has become an every-day matter.

Meanwhile, experimental inquiry has been increasingly active; the laws of animal nutrition are getting to be better understood, the theories have been put to the test of actual experience, and while their value to the farmer has been abundantly verified, weaknesses have been developed and ways in which improvements are wanted have become apparent. We are constantly working toward a clearer understanding of the principles of feeding and a more successful application of them to the practice of the farm. With the rest it has become evident that to meet the demands of both physiological chemistry and practical feeding, the chemist must devise more accurate methods of estimating the nutritive values of feeding stuffs. One means for this is found in the use of the calorimeter, by which the fuel values of the nutrients are estimated. The Station has, with assistance from

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* In an address by the writer before the Connecticut Board of Agriculture, which was published in the report of that board for 1874. During the years 1876–80 the subject was treated in a series of articles in the American Agriculturist, and in 1880 it was set forth still more fully by Prof. Armsby in his valuable "Manual of Cattle Feeding."

Wesleyan University and other sources, begun a series of investigations in this direction, a preliminary report of which is given by Mr. Gibson beyond. As this subject is comparatively new, especially in the United States, a few explanations may be in place.

The two chief uses of the food of animals are: (1) to form the material of the body and make up its wastes, and (2) to yield energy in the form of heat to keep the body warm and muscular power for the work it has to do. In doing the first of these two duties, that of forming the tissues and fluids of the body, the food serves for building and repair. In doing the second, that of yielding energy, it serves as fuel.

Nutrients of Food. Protein, Fats, and Carbohydrates.—By our current methods, the nutritive values of feeding stuffs are expressed in terms of protein, fats, and carbohydrates. The term protein is used to include the nitrogenous compounds of food. Among these are the myosin (lean) of meat, albumen (white) of egg, casein of milk, gluten of wheat, and other similar substances which are often called albuminoids; those which occur in bone and in tendon and the like and are sometimes called gelatinoïds; and others which need not be named here. The albuminoids and gelatinoids are sometimes classed together as proteids. The fats of food include the fats of meat, the fat (butter) of milk, and the oily and fatty substances of plants. The principal carbohydrates are the sugars, starches and gums, which are frequently denominated "nitrogen-free extract," and the cellulose and allied substances which are classed as "crude fiber." It is unfortunate that different writers use different terms for these substances, but it cannot well be otherwise in the present state of our knowledge. Meanwhile, we follow ordinary usage and recognize the three classes of compounds: protein, fats, and carbohydrates. Besides these, our food and drink contain mineral matters and water, but they are generally abundant and are not commonly taken into account in estimates of feeding values.

Uses of Protein.—Of these classes of nutrients, only the protein compounds contain nitrogen, and they alone can form the nitrogenous ingredients which occur in blood, bone, muscle, tendon, skin, hair, etc. The casein and albumen of milk are also derived from the protein of the food. The protein compounds are transformed into fats in the body. And finally, protein serves as fuel.

Uses of Fats.—The fats of the food are stored as fat in the body and are consumed as fuel. The natural purpose of the fat which is stored in the body is that of a fuel supply.

Uses of Carbohydrates.—The carbohydrates, such as sugar and starch, are transformed into body-fat and are consumed as fuel.

The best experimental evidence implies that the protein, fats, and carbohydrates of the food may contribute directly or indirectly to the formation of the fat of milk.

The principal tissue formers of the food, then, are the protein compounds which build up and repair the nitrogenous material of the body, as muscle and bone, and supply the albuminoids of blood, milk and other fluids of the body. The chief fuel ingredients of the food are carbohydrates and the fats. These are either consumed directly or stored as fat to be used as occasion demands. In being used as fuel, the nutrients of the food tend to protect each other and the materials of the body from being consumed.

A well balanced ration for a horse at work or a milch cow or other animal will supply the protein needed for muscle, bone, blood, milk, etc., and the carbohydrates and fats which, in addition to the protein, are needed for fuel to yield heat to keep the body warm and muscular power for work, or are to be stored as fat in the case of fattening animals.

The value of food as fuel, whether it be for immediate consumption or to be stored as body-fat, is measured in terms of potential energy. The unit commonly used is the Calorie, the amount of heat which would raise the temperature of a kilogram of water one degree centigrade (or a pound of water four degrees Fahrenheit). The same word calorie, but spelled with a small c, is used to designate the heat required to raise the temperature of a gram of water a degree. One Calorie is thus equal to 1,000 calories. Instead of this unit of heat we may use a unit of mechanical energy, for instance the foot-ton, which is the force that would lift one ton one foot. One Calorie corresponds very nearly to 1.53 foot-tons.

Within a comparatively few years a number of experiments have been made with animals in the respiration apparatus to learn the proportions in which the several classes of nutrients do one another's work in serving as fuel in the body. At the same time experiments have been made with the calorimeter to determine the heats of combustion of the same materials. The results obtained with the respiration apparatus and with the calorimeter have agreed very closely. That is to say, in supplying the body with fuel, the protein, fat, and carbohydrates of the food, have been found to replace each other in almost exact proportion to their heats of combustion. Thus, in experiments at the physiological laboratory at Munich, Prof. Rubner found the quantities of materials which were equal to 100 parts of fat, to be as follows:

Isodynamic Values for One Hundred Parts of Fat.

Nutritive substances, water-free.	As determined by direct experiments with animals.	As determined by calorimeter.
Myosin, - - - - - -	225	213
Lean meat, - - - - - -	243	235
Starch, - - - - - -	232	229
Cane sugar, - - - - - -	234	235
Grape sugar, - - - - -	256	255

Taking ordinary food materials as they come, the following general estimate has been made for the average amount of energy in one gram of each of the classes of nutrients:

Potential Energy in Nutrients of Food.

	Calories.	Foot-tons.
In one gram of protein, - - - -	4.1	6.3
In one gram of fats, - - - - -	9.3	14.2
In one gram of carbohydrates, - - -	4.1	6.3

These figures mean that when a gram of fat, be it the fat of the food or body-fat, is consumed in the body, it will, if its potential energy be all transformed into heat, yield enough to warm nine and three-tenths kilograms of water one degree of the centigrade thermometer, or, if it be transformed into mechanical energy such as the steam-engine or the muscles use to do their work, it will furnish as much as would raise one ton fourteen and two-tenths feet or fourteen and two-tenths tons one foot. A gram of protein or carbohydrates would yield a little less than half as much energy as a gram of fat. In other words, when we compare the nutrients in respect to their fuel values, their capacities for yielding heat and mechanical power, an ounce of protein of lean meat or albumen of egg is just about equivalent to an ounce of sugar or starch; and a little over two ounces of either would be required to equal an ounce of the fat of meat or butter or the body-fat. The potential energy in the ounce of potein or carbohydrates would, if transformed into heat, suffice to raise the temperature of one hundred and thirteen pounds of water one degree Fahrenheit, while an ounce of fat, if completely burned in the body or in the calorimeter, would yield as much heat as would warm over twice that weight of water one degree.

It would be wrong to assume that such figures as these are absolutely accurate. For that matter, we are to-day only at the beginning of our knowledge of these subjects, and a very large amount of the most laborious, painstaking, and abstract inquiry will be needed to tell satisfactorily what needs to be known. But we are doubtless warranted in using these figures with the distinct understanding that they are tentative and subject to such revision as future research shall indicate.*

The application of these figures to estimating the fuel values of foods is simple. A gram of digestible protein or a gram of digestible carbohydrates is assumed to yield 4.1 and a gram of digestible fat, 9.3 Calories of energy. A given weight of digestible fat is thus taken to be equivalent in fuel value to 2.27 (9.3÷4.1=2.27) grams of digestible protein or carbohydrates.

The potential energy or fuel value of a given quantity of feeding stuff, or of a daily ration, is calculated by multiplying the number of grams of digestible protein and of digestible carbohydrates by 4.1 and the number of grams of digestible fat by 9.3 and taking the sum of these three products as the number of Calories of potential energy in the materials. The computation is made more convenient by taking each per cent. of each nutrient as equivalent to one hundredth of a pound of that ingredient in a pound of the feeding stuff and multiplying by the number of Calories in .01 pound. As .01 pound equals 4.536 grams, .01 of a pound of protein or carbohydrates would thus be assumed to yield (4.536 x 4.1) 18.6, and each .01 pound of fats 42.2 Calories.

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* The more important experimental data bearing upon this subject may be found in articles by Stohmann and others, Landw. Jahrbucher, 13, 513, and Jour. f. Prac. Chem. N. F. Bde. 19-42 *passim*, and by Rubner, Zeitsch, f. Bologie, Bde., 21–25 *passim*. The principal points are explained in an article by the writer in the Century Magazine for July, 1887.

By the view above explained, a proper daily ration for an animal will supply in appropriate forms the protein needed to form the nitrogenous materials of the body and the energy required for heat and muscular work. Our ordinary standards call for certain weights of digestible protein, fats, and carbohydrates per day. Thus the German (Wolff's) standard for milch cows calls for 2.5 pounds of protein, 0.4 pounds of fat, and 12.5 pounds of carbohydrates per day for 1,000 pounds live weight. The potential energy of these would be about 29,600 Calories. In other words, when burned in the animal's body they would yield heat and muscular energy equivalent to that number of Calories.

Fuel Values and Feeding Standards.—This use of fuel values gives a means of simplifying the calculation of rations. It will be understood that the proportions of fats and carbohydrates are only relative, in other words, that one may be diminished if the other be correspondingly increased. If our theories are correct, the important matter is to provide sufficient protein and sufficient total energy without varying too much from the most desirable relative proportions of the fats and carbohydrates. In other words, a daily ration for a milch cow (1,000 pounds live weight) which would furnish 2.5 pounds of digestible protein and enough digestible carbohydrates and fats to make up the 29,600 Calories of energy, would suffice although the relative proportions of the carbohydrates and fats were not the same as this particular standard requires. But it must be borne in mind that the standard itself is only an estimate, an effort to express proportions which approximate the average needs of different animals. A great deal of experimenting with the calorimeter and the respiration apparatus, and a great deal of practical testing of animals in experimental stables and on the farm, will be needed in order to enable us to make such estimates entirely satisfactory. When that research shall be accomplished, its results will have a very great value to the farmer.

The variations in the proportions of nutrients fed to milch cows by intelligent, practical men are illustrated in statistics collected by the New York State Experiment Station.* A circular of inquiry was sent to a number of leading farmers of that State. From the replies were computed the quantities of food and nutrients in the daily rations per cow. Though the figures are not claimed to be entirely accurate they doubtless indicate more or less correctly the methods of feeding in vogue on the better class of dairy farms in the region. Several of the rations are given here.

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*See Bulletin No. 17 (new series) of N. Y. State Station, and Experiment Station Record Vol. 1, pp. 247 and 267.

Kinds and Amounts of Feeding Stuffs in Daily Rations Fed to Milch Cows.

KIND.	1	2	7	8	10	11
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Corn Stover,	10	—	—	—	13	—
Corn Silage,	15	42.	—	50	—	40
Sugar Beets,	10	—	—	—	—	—
Corn Meal,	5	2.8	3	3	—	—
Wheat Bran,	5	2.0	3	7	—	4
Ground Oats,	5	—	—	—	—	—
Clover Hay,	—	9.6	—	—	—	—
Mangolds,	—	12.2	—	—	—	—
Cotton-seed Meal,	—	3.66	—	3	—	2
Meadow Hay,	—	—	12	20	12	3
Linseed Meal,	—	—	3	—	—	—
Oatmeal,	—	—	3	—	—	—
Straw,	—	—	—	—	8	—

Statistics of Cows.— Yields of Milk or Butter.

No.	LOCALITY (in New York).	BREED OF COWS.	Cows in Herd.	Average Weight of Cows.	YIELD OF MILK PER DAY.		Yield of Butter per Year.
					Summer.	Winter.	
				Lbs.	Lbs.	Lbs.	Lbs.
1	Rochester,	Mostly Guernsey,	49	1,000	30	20	—
2	Ithaca,	Grade Holstein,	12	1,122	—	30	—
7	Brockport,	Jersey,	12	—	—	—	320
8	Leonardsville,	Holstein-Friesian and Guernsey,	30	1,000	—	—	470
10	Cambridge,	Brown Swiss,	8	1,150	—	—	156
11	Holland Patent,	Jersey, thoroughbred and grade,	11	—	(*)	(*)	300

* 5,000 pounds per year.

Nutrients and Fuel Values of Daily Rations of Cows.

No.	LOCALITY (in New York).	BREED OF COWS.	DIGESTIBLE NUTRIENTS IN DAILY RATION.				Potential Energy, (fuel value of nutrients of daily ration, Calories.)	Nutritive Ratio.
			Protein.	Fats.	Carbohydrates.	Total.		
			Lbs.	Lbs.	Lbs.	Lbs.	Cal.	
1	Rochester, -	Mostly Guernsey,	1.88	0.68	14.32	16.88	33,000	1: 8.4
2	Ithaca, - -	Grade Holstein, -	2.57	1.12	10.21	13.90	28,490	1: 5.0
7	Brockport, -	Jersey, - -	2.03	0.63	10.03	12.69	25,090	1: 5.6
8	Leonardsville,	Holstein-Friesian and Guernsey, -	3.01	1.27	17.21	21.49	42,970	1: 6.7
10	Cambridge, -	Brown Swiss, -	0.85	0.28	12.61	13.74	26,220	1:15.6
11	Holl. Patent,	Jersey, thoro'bred and grade, -	1.52	0.71	6.59	8.82	18,080	1: 5.4
German standard for milch cows per day for 1,000 pounds live weight, -			2.50	0.40	12.50	15.40	29,590	1: 5.4

The quantities of digestible protein in the daily food per cow vary from nine-tenths of a pound to three pounds, the total digestible nutrients from 8¾ to 21½ pounds, the fuel value from 18,000 to 43,000 Calories, and the nutritive ratio from 1:5.4 to 1:15.6. Such a wide range in the feeding practice of dairymen certainly shows the need of thorough study of this subject.

It is the hope of the officers of this Station that circumstances may hereafter permit an inquiry regarding kinds and amounts of feeding stuffs used by Connecticut dairymen. To do this most satisfactorily, the proper methods for the inquiry must be elaborated, and with the rest the fuel values of the foods must be studied. It is with the last named object in view as well as for the more purely scientific value of the results that the research has been taken of which some of the preliminary work is described by Mr. Gibson in the succeeding article.

INVESTIGATIONS WITH THE CALORIMETER.

BY

H. B. GIBSON.

DESCRIPTION OF APPARATUS.

The calorimeter employed was made after the general plan of those used by Dr. F. Stohmann, and described by him in the *Landwirthschaftliche Jahrbücher* (1884), Vol. XIII. Nos. 4 and 5. It may be briefly described as follows: The outside portion of the calorimeter is a double walled copper vessel covered on the outside and bottom with a thick layer of felt. The space between the double walls is filled with water, and the water jacket thus formed is the outside vessel of the calorimeter proper. Supported within the water jacket by a hard rubber frame is a polished vessel of similar shape but of smaller size, and supported in the same way within this vessel is a second one with the capacity of about two and one-half liters, which holds the water in which the combustion takes place. The top of the apparatus is covered by a hard rubber plate and layer of felt. In this way the water in which the combustion takes place is shut off from the influence of the temperature of the surrounding air by two air spaces, a thick layer of water and a coating of felt.

The platinum combustion cylinder is 6.5 cm. high and 2.5 cm. in diameter, with four small holes in the sides to give easy circulation of water through it when the combustion is finished. The combustion cylinder is placed within a platinum "diving bell" by which it is kept out of contact with the water of the calorimeter. The diving bell may be opened through a tube extending outside of the calorimeter. The apparatus used for stirring the water of the calorimeter and of the water jacket has a vertical motion.

The thermometer, which was made by W. Haak, Jena, is graduated to hundredths of a degree (centigrade) and by means of a low power lens may be read to thousandths of a degree.

The thermal equivalent of the apparatus was found experimentally to be 59 grams of water.

METHOD OF COMBUSTION.

The method of combustion, with one exception to be indicated below, is that used by Stohmann,* and may be briefly described as follows:

The combustion of the substance under experiment is carried on in the presence of an oxygen mixture consisting of 13.33 g. of potassium chlorate and 1.67 g. of manganese dioxide. In the combustion of many substances it is necessary to add from 1 to 2.5 g. of pulverized pumice stone as a diluent to regulate the speed of the burning. One-tenth gram of cane sugar is added to the surface of the mixture to facilitate the communication of the spark of the fuse to the more inert mass below. The time of combustion usually varies from 15 to 30 seconds with the quantity and nature of the substance burned, the amount of pumice stone added and the mechanical condition of the mixture.

About 15 minutes before the insertion of the loaded combustion cylinder 2,000 g. of water are added to the inner vessel of the calorimeter in which the combustion is to take place. The temperature of the water is so regulated that its temperature shall rise during the combustion to about one-half degree above that of the outside water jacket of the calorimeter.

The combustion may be divided into four periods. 1. The removal of the diving bell from the calorimeter, the insertion and lighting of the fuse, and the return of the bell to the calorimeter. 2. The time during which the substance is burned. 3. The following five minutes during which the temperature of the apparatus is coming into approximate equilibrium, and the chloride formed by the decomposition of the potassium chlorate is being brought into solution. 4. A second period of five minutes, during which experimental correction is made for the amount of radiation which has taken place during period 3.

After a series of preliminary combustions, it became evident that the construction of the apparatus was such that it was practically impossible to produce a good circulation of the water of the calorimeter through the diving bell and combustion cylinder during periods 3 and 4 by the ordinary method of stirring. This lack of circulation seemed likely to increase the difficulty in getting samples of the water of the calorimeter at the end of periods 3 and 4 which should fairly represent its content of potassium chloride, and also to retard the attainment of the maximum temperature of the combustion so as to seriously interfere with the value of the experimental correction for radiation which is determined during period 4. To bring about a more thorough circulation, a quantity of air just sufficient to expel the water from the diving bell was. forced into it at intervals of about 20 seconds during periods 3 and 4, and after the lapse of about 5 seconds the pressure removed and the water readmitted while the slow stirring was continued. This arrangement greatly facilitates solution of the chloride and assures the attainment of the maximum temperature early in period 3. The compressed air was led through the water jacket of the calorimeter before being admitted to the bell, and an extended series of experiments showed that no error was introduced by this modification in manipulation.

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* Loc. cit.

METHOD OF DETERMINING THE "CONSTANT."

In this method of combustion, aside from the heat produced by the burning of the substance under experiment, and from the influence of radiation, which latter is directly determinable, the following principal factors influence the result. (1). Positive or heat producing:—Heat produced by the burning of a fixed quantity of kindling material, the fuse, and the paper used to cover the holes of the combustion cylinder, and the heat produced by the decomposition of the potassium chlorate used in the oxygen mixture. (2). Negative or heat absorbing:—The heat absorbed by solution of the chloride formed by decomposition of the potassium chlorate. From these factors it is possible to elaborate a constant correction.

This "constant," of about 1,000 cal., which is due to the accessories of the combustion and not to the substance experimented upon, cannot be determined theoretically, but must be ascertained by experiment.

The method used by us for the determination of the constant is herewith given in detail. Certain factors of the combustion are under experimental control, namely, corrections due to outside influences of temperature, and a variable corresponding to the amount of potassium chloride left undissolved. Those not under direct control are the constant, and the value of the substance to be burned. If either of these unknown quantities can be eliminated the value of the other can easily be found. This may be most easily accomplished by determining the value of the substance under experiment by the following method of difference: The amount of oxidation mixture, paper, fuse and kindling are kept constant and the quantity of substance to be burned made to vary. The difference in the results of the determinations is due solely to the difference in the amount of the substance burned, and from this difference the heat of combustion of the substance under experiment may be accurately determined. For instance, the total amount of heat produced by combustion in experiment No. 86 was 4,940 cal. In this case 1 g. of sugar was burned. In No. 96 the burning of 1.5 g. of the same specimen of sugar produced 6,897 cal. As the only change in the method of combustion was the addition of 0.5 g. of sugar, the difference in the results must be due solely to this cause. Substracting 4,940 cal. from 6,897 cal. 1,957 cal. remain for the value of 0.5 g. of sugar or 3,914 cal. for one gram. By substracting the value of the amount of sugar burned from the total heat produced in the combustion, the value of the constant is obtained. For instance, the value of the constant as shown by No. 86 is 4,940 cal. minus 3,914 cal. or 1,026 cal.

It would of course be possible to find the constant by letting the amount of substance remain the same and varying the quantity of the oxygen mixture used;* but experimental complications render this form of determination much more difficult than the one described.

The results of the experimental determination of the constant by the method described are given below. The first column gives the number of the specimen of sugar (referring to the specimen as described in table No. 50), the second and fourth columns give the number of combustions in which 1 and 1.5 g. of sugar were used, while the third and fifth columns give the experimental values of the series of combustions with these amounts. The sixth column gives the fuel value of one gram of sugar as found by difference, and the last the value of the constant.

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* Stohmann, Loc. cit.

Experimental Data from which the Value of the Constant was Obtained.

KIND OF SUGAR.	1 g. SUGAR.		1.5 g. SUGAR.		Value 1 Gram Sugar.	Value of Constant.
	Number of Combustions.	Value of Sugar plus Constant.	Number of Combustions.	Value of Sugar plus Constant.		
		cal.		cal.	cal.	cal.
1,	7	4931	8	6890	3918	1013
2,	5	4944	6	6912	3936	1008
3,	4	4927	4	6888	3922	1005
4,	5	4932	4	6892	3920	1012
Average,	—	—	—	—	—	**1010**

This constant includes the heat of combustion of the paper covering the holes of the combustion cylinder, and of the fuse, as well as that of the .1 g. of sugar added as kindling. As the constant fixed upon by Stohmann* for the same method of combustion is given without including the .1 g. of sugar, the constant as determined by us may be reduced to the same form for the sake of comparison. This constant, 1,010 cal., less 392 cal. (the value of .1 g. of cane sugar as reported herewith), equals 618 cal. That used by Stohmann is 634 cal., and as the amounts of reagents employed are the same and the quantity of paper and fuse nearly the same in both cases, the results are directly comparable. The constant employed by Dr. Max Rubner† is assumed from the value found by Stohmann (634 cal.).

Table 49, which follows, gives the results expressed in small calories, obtained by the combustion of various carbohydrates and fats, and of stearine and mannite. The second column contains the laboratory number of the combustion. In the first column will be found the description of the substance burned, in the third the quantity taken for the combustion, and in the fourth the total quantity of potassium chloride found in the water of the calorimeter. The fifth column gives the total quantity of heat of the combustion expressed in calories, and the last column the heat of combustion in calories per gram of the substance under experiment.

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* Loc. cit. and Jour. Prak. Chem., 1885, s. 288.

† Zeit. f. Biol., 1885, s. 262.

TABLE 50.

Results (in small calories) of Combustion of Carbohydrates, Fats, Etc.

SUBSTANCE.	Combustion No.	Weight Taken.	Total KCl.	Calorie, including constant (1010).	Calories per Gram.
		g.	g.	cal.	cal.
Cane Sugar.					
1. A well crystalized specimen of rock candy, ground and passed through a round hole .5 mm. in diameter, and dried for several hours at 65° C. (circa)	85	1.0	7.86	4915	3905
	86	1.0	7.78	4940	3930
	87	1.0	7.80	4902	3892
	88	1.0	7.95	4925	3915
	121	1.0	7.88	4953	3943
	122	1.0	7.89	4967	3957
	124	1.0	7.82	4916	3906
	90	1.5	7.99	6922	3941
	91	1.5	7.96	6851	3894
	92	1.5	7.88	6910	3933
	93	1.5	7.88	6920	3940
	95	1.5	7.72	6847	3891
	96	1.5	7.85	6897	3925
	97	1.5	7.82	6929	3946
	125	1.5	7.75	6842	3888
Minimum,	—	—	7.72	—	3888
Maximum,	—	—	7.99	—	3957
Average,	—	—	**7.86**	—	**3921**
2. A well crystalized specimen of cane sugar, furnished as chemically pure by Eimer & Amend, prepared for combustion as 1,	100	1.0	7.91	4927	3917
	101	1.0	7.88	4960	3950
	102	1.0	7.76	4939	3929
	103	1.0	7.85	4927	3917
	110	1.0	7.93	4968	3958
	104	1.5	7.92	6921	3941
	105	1.5	7.76	6900	3927
	106	1.5	7.82	6916	3937
	107	1.5	7.89	6885	3917
	108	1.5	7.92	6950	3960
	109	1.5	7.80	6901	3927
Minimum.	—	—	7.76	—	3917
Maximum,	—	—	7.93	—	3960
Average,	—	—	**7.86**	—	**3935**
3. A well crystalized specimen of cane sugar, furnished by Eimer & Amend, differing somewhat from 2 in physical characteristics,	111	1.0	7.91	4916	3906
	112	1.0	7.88	4934	3924
	113	1.0	7.75	4922	3912
	115	1.0	7.73	4934	3924
	116	1.5	7.89	6884	3916
	117	1.5	7.80	6873	3909
	118	1.5	7.87	6896	3924
	119	1.5	7.82	6898	3925
Minimum,	—	—	7.73	—	3906
Maximum,	—	—	7.91	—	3925
Average,	—	—	**7.84**	—	**3918**

TABLE 50.—*(Continued.)*

	No.	g.	g.	cal.	cal.
Cane Sugar.					
4. Sucrose, prepared and furnished by the kindness of Mr. H. E. L. Horton, of the U. S. Department of Agriculture. Prepared for combustion as 1, - - - - - - -	168	1.0	7.80	4949	3939
	169	1.0	7.88	4928	3918
	170	1.0	7.88	4933	3923
	171	1.0	7.72	4902	3892
	179	1.0	7.95	4946	3936
	172	1.5	7.78	6900	3927
	173	1.5	7.75	6862	3901
	174	1.5	7.76	6878	3912
	178	1.5	7.82	6926	3944
Minimum, - - - - - -	—	—	7.72	—	3892
Maximum, - - - - - -	—	—	7.95	—	3944
Average, - - - - - -	—	—	**7.81**	—	**3922**
5. Rock candy from same source as 1. Precipitated from aqueous solution by alcohol, washed with re distilled ether and dried at 65° C. (circa), - -	45	1.0	7.86	4859	3849
	46	1.0	7.87	4876	3866
	47	1.0	7.81	4863	3853
	48	1.0	7.88	4862	3852
	57	1.0	7.80	4892	3882
	58	1.0	7.92	4924	3914
	59	1.0	7.89	4953	3943
	60	1.0	7.92	4923	3913
	68	1.0	7.76	4872	3862
	99	1.0	7.88	4920	3920
	54	1.25	7.84	5957	3958
	55	1.25	7.84	5948	3950
	66	1.25	7.85	5978	3974
	49	1.5	7.76	6859	3899
	51	1.5	7.85	6898	3925
	52	1.5	7.89	6925	3943
	61	1.5	7.79	6938	3952
	98	1.5	7.87	6922	3941
Minimum, - - - - - -	—	—	7.76	—	3849
Maximum, - - - - - -	—	—	7.92	—	3958
Average, - - - - - -	—	—	7.85	—	3910
Minimum, 1, 2, 3, 4 and 5, - -	—	—	7.72	—	3849
Maximum, 1, 2, 3, 4 and 5, - -	—	—	7.99	—	3960
Average, 1, 2, 3, 4 and 5, - . -	—	—	**7.84**	—	**3921**
Milk Sugar.					
6. Crystalized, containing 5.37 % water,	193	1.25	7.85	5666	3725
	194	1.25	7.84	5660	3720
	132	1.5	7.88	6557	3698
	195	1.5	7.72	6559	3699
	196	1.5	7.81	6569	3706
Minimum, - - - - - -	—	—	7.72	—	3698
Maximum, - - - - - -	—	—	7.88	—	3725
Average, - - - - - -	—	—	**7.82**	—	**3710**
Average, crystalized 5 % water, -	—	—	—	—	**3724**
Average, water-free, - - -	—	—	—	—	**3920**

TABLE 50.—*(Continued.)*

	No.	g.	g.	cal.	cal.
Cane Sugar Group.					
Average 66 combustions and 6 specimens,	—	—	—	—	**3921**
Dextrose.					
7. Prepared and furnished by Mr. H. E. L. Horton as 4, containing 0.29 % water,	185	1.0	7.94	4759	3749
	184	1.25	7.96	5673	3730
	182	1.50	7.83	6637	3751
	183	1.50	7.91	6625	3743
Average,	—	—	**7.91**	—	**3743**
Average, water-free,	—	—	—	—	**3754**
Starch.					
8. Arrow-root. At time of combustion specimen contained 2.31 % water and .23 % ash,	149	1.25	7.74	6109	4079
	151	1.25	7.70	6078	4054
	150	1.50	7.75	7061	4034
	152	1.50	7.73	7083	4049
Average,	—	—	**7.73**	—	**4054**
Average water and ash-free,	—	—	—	—	**4160**
9. Corn starch. At time of combustion specimen contained 1.75 % water and .50 % ash,	154	1.25	7.81	6121	4089
	156	1.50	7.76	7123	4075
	201	1.50	7.71	7092	4055
Average,	—	—	**7.76**	—	**4073**
Average water and ash-free,	—	—	—	—	4167
Average of 8 and 9,	—	—	—	—	**4164**
Mannite.					
10. A well crystalized water-free specimen,	133	1.0	7.83	4921	3911
	191	1.0	7.85	4983	3973
	192	1.25	7.81	6965	3964
	135	1.50	7.78	6979	3979
	136	1.50	7.81	6959	3966
Average,	—	—	**7.82**	—	**3959**
Stearine.					
11. Commercial, containing no nitrogen, and dried over concentrated sulphuric acid,	20	.5000	7.91	5691	9362
	26	.5000	7.96	5700	9380
	28	.5000	7.97	5712	9404
	30	.5000	7.91	5705	9390
Average,	—	—	**7.94**	—	**9384**
12. Commercial. Dried over concentrated sulphuric acid,	137	.5000	7.88	5661	9302
	138	.5000	7.90	5668	9316
	139	.5000	7.81	5675	9330
Average,	—	—	**7.86**	—	**9316**
Average of 11 and 12,	—	—	—	—	**9355**
Tallow.					
13. From several specimens of beef fat, filtered and water-free,	144	.5157	7.88	5872	9428
	145	.4952	7.83	5661	9392
	146	.5025	7.86	5739	9411
Average,	—	—	**7.86**	—	**9410**
14. From beef suet, filtered and water-free,	202	.5584	7.80	6246	9377
	203	.5607	7.91	6305	9444
	204	.5056	7.84	5787	9448
	205	.5279	7.88	6018	9487
Average,	—		**7.86**	—	**9439**
Average of 13 and 14,	—		—	—	**9327**

TABLE 50.—*(Continued.)*

	No.	g.	g.	cal.	cal.
Mutton Fat.	165	.5173	7.90	5943	9536
15. From kidney fat, filtered and water-free.	166	.5010	7.88	5792	9545
	167	.5003	7.78	5767	9508
Average,	—	—	**7.85**	—	**9530**
Pork Fat.	161	.5086	7.88	5841	9499
16. From leaf lard, filtered and water-free,	162	.5251	7.92	6022	9545
	163	.5195	7.90	5953	9515
	164	.5078	7.97	5834	9500
Average,	—	—	**7.92**	—	**9515**
Average of 13, 14, 15 and 16,	—	—	—	—	**9474**
Butter Fat.	197	.5025	7.87	5623	9180
17. Filtered and water-free,	198	.5062	7.81	5636	9139
	199	.5144	7.84	5746	9207
	200	.5059	7.89	5671	9214
Average,	—	—	**7.85**	—	**9185**
Olive Oil.	186	.5168	7.96	5919	9499
18. Water-free,	187	.5074	7.92	5803	9446
	188	.5705	7.91	6417	9478
	189	.6609	7.87	7262	9460
Average,	—	—	**7.92**	—	**9471**
Sperm Oil.	206	.5246	7.85	6250	9989
19. Water-free,	207	.5545	7.75	6562	10013
	208	.6608	7.70	7618	10000
Average,	—	—	**7.77**	—	**10001**

COMPARISON OF THE RESULTS HEREWITH REPORTED WITH THOSE OBTAINED BY STOHMANN AND BERTHELOT.

The values of the carbohydrates and mannite groups as observed by Stohmann and Berthelot, as compiled by Stohmann, are chosen for the comparison. Those observed by Stohmann were obtained by the use of the method described by himself* and those by Berthelot by combustion in presence of highly compressed oxygen,† while those herewith reported were obtained by the method of Stohmann. The results in this compilation are expressed in Calories per molecule, which are obtained by multiplying the Calories (1,000 calories equal 1 Cal.) per gram by the molecular weight.

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* Loc. cit. and Jour. Prak. Chem., 1887, s. 132.

† Compt. Rend. 102, 1,211 and 1,284. Ann. Chim. (6) 10, 441. Compt. Rend. 104, 1,571 and 1,574.

TABLE 51.

Heats of Combustion of the Carbohydrates and Mannite Groups. Results in Calories per Molecule, Compiled from Values observed by Berthelot and Stohmann, compared with Values herewith reported.

	Berthelot.	Stohmann.	Reported Herewith.
	cal.	cal.	cal.
Dextrose Group.			
Dextrose, water-free,	677.2	664.6	675.7
Lactose,	—	658.6	—
Arabicose,	—	665.1	—
Milk sugar, crystalized,	679.9	659.3	—
Average,	**678.5**	**661.9**	**675.7**
Cane Sugar Group.			
Cane sugar,	1355.0	1322.2	1341.0
Milk sugar, water-free,	—	1325.9	1340.6
Melitose, water-free,	—	1327.0	—
Average,	**1355.0**	**1325.0**	**1340.8**
Starch Group.			
Starch,	684.9	667.9	675.6
Cellulose,	681.8	671.7	—
Inuline	678.3	659.3	—
Dextrine,	667.2	—	—
Average,	**678.0**	**666.3**	**675.6**
Mannite Group.			
Mannite,	728.5	716.9	720.5
Dulcite,	729.4	711.3	—
Average,	**729.0**	**714.1**	**720.5**

SUMMARY.

The following gives in tabular statement the results of the combustion of various carbohydrates, fats, etc., herewith reported upon:

Heats of Combustion of Various Carbohydrates, Mannite, Stearine, and Various Fats.

Substance.	Number of Specimens.	Number of Combustions.	Small Calories per Gram.
			cal.
Cane Sugar,	5	61	3921
Milk Sugar, crystalized,	1	5	3724
Milk Sugar, water-free,	1	5	3920
Dextrose,	1	4	3754
Starch,	2	7	4164
Mannite,	1	5	3959
Stearine,	2	7	9355
Fat of Beef,	2	7	9427
Fat of Sheep,	1	3	9530
Fat of Swine,	1	4	9515
Butter Fat,	1	4	9185
Olive Oil,	1	4	9471
Sperm Oil,	1	3	10001

While the details of the above investigation have been carried out and the results are reported by myself, I desire to add that they have had the earnest attention of Prof. Atwater, by whose aid and counsel they have been made possible.

METEOROLOGICAL OBSERVATIONS.

BY

C. S. PHELPS.

The season is a most important factor in the production of crops. In field experiments it becomes very important to know what part of the successes or failures are due to peculiarities of the season. Simple observations on the rainfall, temperature, and relative humidity of the air, throw considerable light on this subject. The value of such observations depends, first, on the accuracy of the instruments and the regularity and care exercised in their use, and on the number of years that the observations have been conducted. The Station equipment consists of the ordinary instruments for obtaining temperature, pressure of the air, humidity, rainfall, snowfall, and velocity of the wind, uniform with those in use by the United States Signal Service. The thermometers and barometers are placed in a small thermometer house, especially constructed for the purpose, with sides and bottom of open shutters and lattice. The roof is double and insulated by a dead air space and by asbestos paper beneath the shingles. The house is firmly set two and one-half feet above the ground, and at a sufficient distance from any building or tree to allow free exposure. Three times daily, at 7 A. M., 2, and 9 P. M. the temperature, pressure, relative humidity of the air, direction of the wind, and general state of the weather are recorded. The maximum and minimum temperatures, the total movement and maximum velocity of the wind and the rainfall are recorded once in twenty-four hours. Monthly blanks furnished by the New England Meteorological Society are filled out at the close of each month, one copy being sent to the Society and another put on file at the Station.

The Station and most of the farmers conducting experiments under our supervision have made weekly crop reports to the above Society during the greater part of the growing season. In return they have received weekly crop bulletins, published by the Society in co-operation with the United States Signal Service.

These bulletins were sent out on Monday of each week during the months of June, July, August, and September. They give general conditions of crops and the state of the weather for the previous week in all of the New England States, and have been read with much interest by all receiving them.

The rainfall for the year (48.9 in.) as obtained at the Station was very close to the yearly average for the State. Six regular stations of the New England Meteorological Society having observations extending over a period of ten or more years, show an average yearly precipitation of 49.1 in. The rainfall was generally well distributed through the year; no month, except November, showing any marked deficiency.

The amount of rain was greatest during the spring months and in the late summer and early part of fall. The year opened with mild weather, January being 7° warmer than the average for this State. The snowfall was light and the total precipitation was 1.6 in. below the average. The extremes of temperature were greater during February than for January. The temperature for the month was 4° above the average while the percipitation was about an inch below.

March was characterized by an unusual amount of cloudy and foggy weather. The total precipitation was about 1.7 in. above the average.

The spring was quite early, no damaging frosts occurring after April 29. The rainfall for April was light, but was followed by a heavy fall during May. The temperature for May was 2° below the average. Grass made good growth, but the cool weather tended to retard the growth of most cultivated crops.

The summer was dry and generally rather cool. The rainfall for June was sufficient for the needs of most crops. During July, however, the drouth became quite severe. Less than one-third of an inch of rain fell during the first twenty-three days of the month. Heavy rains during the last week, however, brought the total up to 2.81 in. The temperature for the three summer months fell 3° below the average for the State. Cloudy weather and rain were common through September, the rainfall being 3.6 in. above the average, while there was 43 per cent. of cloudy days. The first killing frost occurred on the 25th, leaving a growing period of 148 days since the last damaging frost in the spring.

The rainfall for October was about an inch above the average for that month. A large amount of cloudy and damp weather delayed the corn harvest somewhat.

November, however, gave much pleasanter weather, the rainfall being less than for any month in the year.

December was marked by steady cold weather, especially during the last half of the month. The temperature fell 6.4° below the average for the State.

Through the kindness of the officers of the New England Meteorological Society we are able to publish the rainfall from their stations. Table 52 gives the rainfall as recorded during the growing season in seventeen localities in the State. Table 53 gives the summary of observations made by the Station at Storrs.

TABLE 52.

Rainfall During the Six Months Ending October 31st, 1890.

OBSERVATIONS MADE AT SEVENTEEN LOCALITIES IN THE STATE.

LOCALITY.	OBSERVER.	INCHES PER MONTH.						
		May.	June.	July.	August.	September.	October.	Total.
Falls Village,	M. H. Dean,	4.73	3.24	6.43	6.06	6.00	5.40	31.86
Oxford,	H. R. Stevens,	5.62	2.56	4.23	4.47	5.11	7.17	29.16
Waterbury,	N. J. Welton,	5.97	3.26	4.96	4.50	4.98	6.89	30.56
Shelton,	F. B. Wheeler,*	5.14	2.80	4.95	—	6.24	8.69	—
New Haven,	Signal Station,*	4.24	3.12	6.59	2.67	5.38	7.63	29.63
Wallingford,	Mrs. D. F. Harrison,*	5.66	3.34	4.83	—	5.66	7.21	—
New Britain,	A. C. Blake,	5.66	2.73	4.48	3.01	3.86	—	—
Hartford,	Rev. S. Hart,*	4.73	2.86	5.25	4.05	3.83	7.57	28.29
Canton,	G. J. Case,*	5.01	3.42	4.66	5.36	5.54	7.88	31.87
W. Simsbury,	S. T. Stockwell,	4.82	2.92	4.77	5.23	5.72	6.49	29.95
S. Manchester,	K. B. Loomis,	6.06	2.74	3.89	4.16	4.99	6.53	28.37
Middletown,	H. D. A. Ward,*	5.51	2.16	4.16	4.66	5.97	7.52	29.98
New London,	Signal Station,*	4.51	2.94	3.07	2.43	5.51	6.43	24.89
Lebanon,	J. H. Tucker,	4.31	3.33	2.05	3.88	5.66	7.11	26.34
Mansfield,	E. A. Bailey,	6.33	2.79	2.81	4.26	7.19	5.25	28.63
N. Woodstock,	L. H. Healey,	6.30	2.87	3.10	4.95	6.10	6.34	29.66
Voluntown,	Rev. E. Dewhurst,*	3.65	3.26	2.79	4.67	4.91	8.47	27.75
Averages,	- - - - - -	5.19	2.96	4.29	4.29	5.45	7.04	29.07

* New England Meteorological Society Observer.

TABLE 53.

Meteorological Summary for 1890.

OBSERVATIONS MADE AT THE STATION BY E. A. BAILEY AND C. B. LANE.*

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.	Total.
Highest barometer, - - -	30.83	30.68	30.54	30.56	30.33	30.28	30.26	30.26	30.39	30.42	30.37	30.64	30.46	—
Lowest barometer, - - -	29.46	29.42	29.47	29.46	29.58	29.72	29.72	29.55	29.71	29.36	29.45	29.45	29.53	—
Mean barometer, - - -	30.18	30.09	29.99	30.09	29.96	29.98	30.03	30.01	29.81	29.89	30.01	30.05	30.01	—
Highest temperature, - -	61.1	64.0	65.6	74.4	77.1	83.0	89.0	84.4	80.2	74.0	63.8	47.8	72.0	—
Lowest temperature, - - -	7.2	-4.6	-.7	21.6	34.5	43.8	42.4	44.9	33.0	31.8	13.0	-1.8	22.1	—
Mean temperature, - - -	32.0	31.7	30.8	44.7	54.9	63.3	67.5	66.0	59.5	47.6	37.9	23.4	46.6	—
Relative humidity, - - -	77.2	81.3	81.2	66.7	78.6	76.7	77.6	81.7	86.7	79.4	74.6	74.3	78.0	—
Total precipitation, - - -	2.66	3.28	6.12	3.15	6.33	2.79	2.81	4.26	7.19	5.25	.82	4.21	—	48.87
Number of days with precipitation of .01 inches or more,	10	12	17	10	17	10	7	13	12	17	6	13	—	144
Number of clear days, - -	8	5	6	15	8	11	9	5	10	9	9	10	—	105
Number of fair days, - - -	9	10	16	9	15	10	14	18	7	8	15	8	—	139
Number of cloudy days, - -	14	13	9	6	8	9	8	8	13	14	6	13	—	121
Total movement of wind in miles,	9585	8860	9290	7605	6888	—	5209	5537	4535	6962	—	10259	—	—
Maximum velocity, - - -	60	55	38	35	30	—	32	45	22	55	45	60	—	—

* For November and December.

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Publications of the Station.

The publications of the Station will be mailed to all citizens of Connecticut and to Granges, Farmers' Clubs and other agricultural organizations who ask for them, and so far as circumstances permit, to those who apply from other States. Requests for publications and business communications should be addressed to

STORRS SCHOOL AGRICULTURAL
EXPERIMENT STATION,
TOLLAND COUNTY. STORRS, CONN.

STATE OF CONNECTICUT.

FOURTH ANNUAL REPORT

—OF THE—

STORRS SCHOOL

AGRICULTURAL EXPERIMENT STATION,

STORRS, CONN.

1891.

Printed by Order of the General Assembly.

MIDDLETOWN, CONN.:
PELTON & KING, PRINTERS AND BOOKBINDERS.
1892.

PUBLICATIONS OF THE STATION.

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STORRS SCHOOL AGRICULTURAL
EXPERIMENT STATION,
STORRS, CONN.
Tolland County.

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BOARD OF TRUSTEES

—OF THE—

STORRS AGRICULTURAL SCHOOL.

His Excellency Morgan G. Bulkeley.

E. H. Hyde,
W. E. Simonds,
S. W. Johnson,
J. H. Hale,
T. S. Gold,
J. M. Hubbard,
H. C. Miles,
E. C. Pinney.

The Station is located at Mansfield (P. O. Storrs), as a department of the Storrs Agricultural School. The Chemical and other more abstract work is carried out at Wesleyan University, Middletown.

OFFICERS OF THE STATION.

EXECUTIVE COMMITTEE.

T. S. Gold, West Cornwall, J. M. Hubbard, Middletown,	*Of the Board of Trustees of Storrs Agricultural School.*
B. F. Koons, Storrs,	*Principal of the School.*

TREASURER.

Henry C. Miles, Milford.

STATION STAFF.

W. O. Atwater, Middletown,	*Director.*
C. D. Woods, Middletown,	*Vice-Director and Chemist.*
C. S. Phelps, Storrs,	*Agriculturist.*
E. A. Bailey, Storrs,	*Assistant Agriculturist.*
H. M. Smith, Middletown,	*Assistant Chemist.*

Report of the Executive Committee.

To His Excellency Morgan G. Bulkeley,
Governor of Connecticut:

In accordance with the resolution of the General Assembly concerning the congressional appropriations to Agricultural Experiment Stations, and an Act of the General Assembly, approved March 6th, 1889, relating to the publication of Reports of the Storrs School Agricultural Experiment Station, we have the honor to present herewith the Fourth Annual Report of that Station, namely, that for the year 1891.

The policy of the Station with reference to the scope and character of its work has been continued as in other years. More attention has been given to the food of man during this year than in any previous year, and less work has been done in the analyses of field crops.

Through the generosity of the late Hon. J. W. Alsop, M. D., a greenhouse has been erected at Middletown, and apparatus has been purchased for the continuance of experiments upon the acquisition of atmospheric nitrogen by growing plants, with an especial view to test carefully the fixation of free nitrogen of the air. Dr. Alsop's gift for this purpose was five hundred dollars, of which three hundred and seventy-five dollars was made available previous to July 1st, as appears in the Annual Report of the Treasurer, and the rest later in the calendar year.

The Director, Prof. W. O. Atwater, continued in charge of the office of Experiment Stations of the United States Department of Agriculture during the earlier part of the year, and later has been in Europe. He has thus spent only a portion of the time in Middletown, and in consequence has been able to exercise only a general supervision of the work of the Station. In his absence the Vice-Director, Chas. D. Woods, has had charge of the work of the Station, and is responsible for the details of its operations.

The following changes in the Station staff have been made during the year: April first, Mr. Phelps was made professor of agriculture in the Storrs School, and in consequence was relieved from duty as Vice-Director and appointed to the position of Agriculturist to the Station. Mr. Woods was at the same time made Vice-Director of the Station, and Mr. E. A. Bailey, a former assistant in field experiments, was appointed Assistant Agriculturist.

July first, Mr. H. B. Gibson, who had been the very efficient assistant chemist to the Station for three years, resigned to accept a traveling fellowship from Harvard University. He is at present studying in Leipsic, Germany. Mr. H. M. Smith was appointed Assistant Chemist in his stead.

On September first, Mr. C. B. Lane resigned the position of assistant in farm experiments to enter the Massachusetts Agricultural College.

The Committee refer to the accompanying report of the Treasurer for details of expenditure, and to that of the Director and his associates for the history of the work accomplished.

Respectfully submitted,

T. S. GOLD,
J. M. HUBBARD,
B. F. KOONS,
Executive Committee.

REPORT OF THE TREASURER FOR THE FISCAL YEAR ENDING JUNE 30, 1891.

The following summary of receipts and expenditures is made out in accordance with the form recommended by the Association of American Agricultural Colleges and Experiment Stations, and approved by the United States Treasury Department:

TABULAR STATEMENT OF RECEIPTS AND EXPENDITURES.

RECEIPTS.

U. S. Treasury,	$7,500 00
Hon. J. W. Alsop, through Wesleyan University,	375 00
Sale of produce and dairy products,	304 07
Balance for 1889–90,	1 53
	$8,180 60

EXPENDITURES.

Salaries,	$3,962 41
Building,	375 00
Building greenhouse, Alsop fund,	126 93
Case, pot experiments,	90 88
Traveling expenses,	230 96
Executive Committee,	95 99
Stationery,	107 71
Postage, telegraph and telephone,	150 47
Treasurer,	52 40
Fixtures, not permanent,	52 90
Bulletins and reports,	496 56
Library,	2 50
Field experiments, labor,	223 87
Field experiments, other than labor,	283 65
Team,	92 88
Feeding experiments,	469 98
Student and other labor,	335 78
Apparatus, immediate,	288 26
Apparatus, permanent,	66 02
Chemicals,	129 58
Coal, gas and oil,	302 12
Hardware and lumber,	43 90
Freight, express and cartage,	133 02
Dietary investigation,	19 46
Insurance,	16 28
Incidentals,	26 54
Balance in treasury,	4 55
	$8,180 60

HENRY C. MILES,
Treasurer.

This will certify that we have examined the accounts of Henry C. Miles, Treasurer of the Storrs School Agricultural Experiment Station, for the fiscal year ending June 30th, 1891, compared the vouchers therewith and find the same to be correct, and that there is a balance in said Treasurer's hands at the close of said year amounting to $4.55.

GEO. F. LINCOLN, } *Auditors of*
D. WARD NORTHROP, } *Public Accounts.*

HARTFORD, December 10, 1891.

Report of the Director.

The lines of experimental work in which the Station has been engaged during the past year are, for the most part, in continuation of those previously begun. They have been as follows:

1. Co-operative field experiments with fertilizers by the Station and by farmers on their own farms in different parts of the State. These experiments are the same in character and scope as those of previous years.
2. Observations on the growth of grass and forage plants at the Station and elsewhere, with especial reference to the cultivation of legumes.
3. Experiments upon the acquisition of atmospheric nitrogen by growing plants.
4. Meteorological observations at the Station throughout the year, and observations of the rainfall in connection with the field experiments in different parts of the State during the growing season.
5. Experimental studies of the bacteria of milk and their action.
6. Investigations with the calorimeter upon the heats of combustion of materials used as food for domestic animals and man.
7. Feeding experiments with milch cows.
8. Investigations of dietaries and studies of the chemical composition of the food of man. The studies of dietaries have been made in connection with the U. S. Department of Labor.

The chemical analyses made have consisted of the analyses of milk, butter, feeding stuffs, and food materials.

My duties in connection with the Office of Experiment Stations of the Department of Agriculture at Washington and in Europe, have been such as to leave but little time for the Station work, and I have therefore been able, during the larger part of the past year, to exercise only a general supervision of its operations. During my absence Mr. Chas. D Woods, Vice-Director of the Station, has served as acting Director.

W. O. ATWATER,
Director.

FORAGE CROPS.

BY C. S. PHELPS.

During the past two years the Station has grown a variety of fodder crops for feeding to milch cows during the summer months. The system practiced is what is known as soiling, or the feeding of animals in the stables, during the growing season, largely or wholly on green forage. The practice of soiling is especially valuable on high priced lands in proximity to cities and towns, as land in such localities is often too valuable to be used for pasturage. The advantages claimed for the soiling system may be summed up as follows: A comparatively small amount of land is required; the food supply can be closely regulated; the animal does not waste its energy in searching for and obtaining its food; and, finally, the manure may be all preserved for use in growing cultivated crops.

In soiling it is important to have a succession of fodders throughout the growing season, with each in its best stage of growth for feeding. There should be no breaks in the succession, and each crop should be used as nearly as possible at the time when it contains the largest amount of valuable food constituents. Fodder crops are generally considered to be in the best condition for feeding when in early bloom. If fed much before this time they will not have made full growth, and light yields will result; while if allowed to remain standing till past the flowering period, the fodder becomes woody and is not as freely eaten nor as completely digested. The best results seem to be obtained when the fodder from a single planting or sowing is not fed longer than ten to twelve days. The same kind of crop may be made available for longer periods by planting or sowing small plots successively, and feeding from these as the fodder on each reaches its best stage of growth.

The forage crops grown during 1891 consisted of wheat fodder, clover and grass, oats and peas, oats and vetch, clover rowen, Hungarian, cow peas, and barley and peas. These gave a succession of green fodders lasting from June 3d to November 1st.

Wheat Fodder.—The Clawson variety of wheat was sown at the rate of two bushels per acre, October 10th, 1890, on about one-fourth acre of land that had produced a crop of cow peas the same year. The wheat wintered well, but appeared rather thin. April 28th nitrate of soda was applied at the rate of 160 pounds per acre. This improved the color and caused a rapid growth. Owing to the late seeding, and the small rainfall during the latter half of May, the crop was thin and light. The fodder was fed from June 3d to the 14th, and was well eaten by milch cows. To obtain a heavy yield, the wheat should be sown early in September, on well manured land, and at the rate of two and one-half to three bushels per acre. Wheat sown at this time will make good forage for about three weeks, beginning May 15th to 25th, according to the season. The feeding should begin when the heads are about half grown.

Clover, and Clover and Grass.—A mixture of about equal parts of clover and grasses was fed June 14th to the 25th. This fodder came from the grass lands of the Station, and was used because no other food was available at that time. In this connection, it may be well to refer to the importance of clover for green feeding. The experience of some of our best farmers has shown that clover sown after winter grain, during the latter part of July, affords excellent forage either for feeding green or for hay. A good "catch" is generally gotten at this time, and the clover becomes firmly rooted by winter, and hence is not liable to be thrown out by the freezing and thawing of the ground. Clover is one of our richest nitrogenous fodders, and can be fed for about two weeks, early in June, after which it will produce a good second crop that will be available early in August, and on rich lands a third crop, about September 20th, is quite common.

Oats and Peas.—The soil upon which this crop was grown was a heavy loam, with a compact clayey subsoil. The field had been heavily manured with stable manure during the previous winter. The seed was sown at the rate of two bushels of field peas and two of oats, per acre. One-fourth acre of land was used, one half of this area being sown April 17th and the balance April 29th. The growth was rapid and heavy. The proportion of oats was sufficient to keep the peas up from the ground, until the latter part of the feeding period, when the crop was somewhat lodged by a heavy rain-storm. Feeding from the first sowing was begun June 25th and continued until July 11th. The second sowing was not as heavy, but gave good feed from July 11th to the 18th. July 1st the fodder from two average square rods of the first section sown gave a yield at the rate of 15.5 tons per acre. July 15 the yield on the second section was estimated in the same way, at the rate of 13.4 tons per acre. A mixed fodder of oats and peas gives one of the best crops for soiling, during the early part of July, that we have yet tried. The crop is well worthy of trial by our farmers, either for feeding green or for making hay.

Oats and Vetch.—Three-fourths of an acre of land adjoining the area sown to oats and peas, was seeded May 6th to oats and vetch. Scotch vetch, a larger and more vigorous grower than the English variety, was sown at the rate of one and one-half bushels per acre, with oats at the same rate. A portion of the crop was fed green from July 18th to the 28th, and the balance was cut and dried for hay. The yield on the section from which the crop was fed green was at the rate of 12.1 tons per acre. Oats and vetch sown in these proportions gave a fodder quite similar in composition to the oats and peas. The vetch, however, is not as coarse as peas, is more readily dried for hay, and is not as apt to lodge. The chief objection to the substitution of vetch for peas is the cost of the seed ($3.00 per bushel). If the seed could be imported at a moderate cost, or if it can be profitably grown in this country, we would be disposed to recommend vetch as a most valuable fodder plant.

Hungarian.—A small area, having a medium loam soil, was sown to Hungarian May 28th, at the rate of one bushel per acre. The drouth early in the season caused a light growth, but a fair crop was produced, and furnished feed from July 28th to August 3d. Another small area was seeded to the same crop June 25th, and furnished feed from August 19th to the 27th. The crop from the later sowing was lighter than that from the earlier. The best time for sowing this crop is June 1st to 10th, and on well manured land the crop will be ready to feed in from eight to ten weeks. A quick acting fertilizer, with a large proportion of nitrogen, seems to give the best results on this crop.

Clover Rowen.—This crop was fed from August 3d to the 18th, and came from a field that had produced a crop of timothy and clover in June. The proportion of timothy in the second crop was very small, and hence the fodder was highly nitrogenous. This fodder crop produced a marked effect on the milk flow and gave the most valuable lot of forage, judging from the results on the products, of any crop fed throughout the summer.

Cow Peas.—This fodder plant has been grown by the Station for the past three years. The results have been generally satisfactory, and where the crop has been grown on warm soils with a liberal quantity of mineral fertilizer fair yields have been obtained. The peas showed a few blossoms and produced a small quantity of seed. Most of the area seeded to this crop was fertilized at the rate of 200 pounds of dissolved bone-black and 200 pounds of muriate of potash. A small area, to which nitrogen was supplied in addition to the above, appeared to give no increase in crop. This fodder plant furnished good feed from September 9th to the 30th.

Three years' experience with this valuable fodder plant leads us to recommend it for green feeding or ensilage. The crop can be advantageously fed from about September 1st to the 20th, or until injurious frosts occur. The yield this year (1891) was at the rate of 8 tons per acre, while in 1890 the yield was 10.9 tons per acre. This difference is quite largely due to differences in varieties. The Clay variety was sown last season. This year the same variety was ordered, but owing to the loss of a letter a second order had to be sent, and the supply of seed of this variety had meantime become exhausted. Seed may be obtained of T. W. Wood, Nos. 8–10 South 14th street, Richmond, Virginia, and should be ordered not later than March. Owing to the earlier season in the South the seed becomes scarce long before time for planting in this latitude. The best variety for forage is the Clay. From our experience we feel warranted in recommending the following treatment for the crop:

Select a deep, warm loam soil with an open subsoil. If the soil is moderately fertile, mineral fertilizers only need to be used. On the Station land, 600 to 800 pounds per acre of a mixture consisting of two-thirds dissolved bone-black and one-third muriate of potash has given good results. On some poor soils a little nitrogen may be advantageously added. Sow from June 1st to the 10th in drills two and one-half feet apart, at the rate of one bushel per acre. Cultivate frequently during the first part of the summer, or until the plants are ten to twelve inches high. The crop generally makes a slow growth when small, but a warm soil and frequent cultivation hasten the growth early in the season. Feed green or preserve in the silo before danger of damaging frosts. The stems are too coarse, and the plant generally too succulent, to be easily made into hay.

Barley and Peas.—The area of land from which oats and peas and oats and vetch had been fed during July, was plowed early in August and seeded the 11th with barley and field peas at the rate of two bushels of each per acre. A complete fertilizer was applied at the following rates per acre: 160 pounds of pulverized tankage, 96 pounds of nitrate of soda, 200 pounds of dissolved bone-black, 120 pounds of blood, bone and meat, and 200 pounds of muriate of potash. The dry, warm weather during the latter part of September checked the growth somewhat and the yield was not as heavy as in previous years. This crop furnished feed from October 8th to November 1st. Peas and barley are not injured by frost, and if the fall months are cool and moist a large amount of valuable forage may be produced. The crop comes at a time when pasture feeds are generally poor, and produces a most valuable supplementary feed where pasturage is the chief dependence. The peas should be covered three to four inches deep, while the barley should be lightly harrowed in.

A SERIES OF CROPS FOR SOILING.

In arranging a series of crops for soiling throughout the entire summer, it becomes important to know the best times for sowing or planting, and when the crops will best serve for feeding. The time of seeding and of feeding must vary somewhat with the climate and season, hence fixed dates cannot be given. From three years' experience and observation in the practice of soiling, we are disposed to recommend the following for central Connecticut:

KIND OF FODDER.	Amount of Seed Per Acre.	Approximate Time of Seeding.	Approximate Time of Feeding.
1. Rye fodder, - - -	2½ to 3 bush.	Sept. 1.	May 10–20.
2. Wheat fodder, - - -	2½ to 3 bush.	Sept. 5–10.	May 20, June 5.
3. Clover, - - - -	20 lbs.	July 20–30.	June 5–15.
4. Grass (from grass lands), -			June 15–25.
5. Oats and peas, - - -	2 bush. each.	April 10.	June 25, July 10.
6. Oats and peas, - - -	2 bush. each.	April 20.	July 10–20.
7. Oats and peas, - - -	2 bush. each.	April 30.	July 20, Aug. 1.
8. Hungarian, - - -	1½ bush.	June 1.	Aug. 1–10.
9. Clover rowen (from 3), -			Aug. 10–20.
10. Soja beans, - - -	1 bush.	May 25.	Aug. 20, Sept. 5.
11. Cow peas, - - -	1 bush.	June 5–10.	Sept. 5–20.
12. Rowen grass (from grass lands), - - - -			Sept. 20–30.
13. Barley and peas, - -	2 bush. each.	Aug. 5–10.	Oct. 1–30.

METEOROLOGICAL OBSERVATIONS.

BY E. A. BAILEY.

Observations similar to those of 1890, which were published in the Report of that year, have been continued by the Station and by most of the farmers conducting experiments under our supervision. A number of the observers reported weekly to the New England Meteorological Society, and in return received the New England Crop Bulletins. These bulletins give the general condition of crops, and a summary of the weather for the past week in the North Atlantic States.

The rainfall for the year (51.6 inches) as measured at the Station was a little in excess of the average for the State. It was generally well distributed through the year, except for the months of May and June. The fall of snow from January to May exceeded the average, while none fell during November and December; this made the snowfall for the year about the usual depth.

The temperature for the first two months of the year was a little above the average, while March gave the coldest weather (zero) of the season. The mean for April was above the normal, and the spring opened quite early. The last severe frost occurred May 5th.

During the last of May and the first half of June, the weather was warm with very little rain, causing a drought of moderate severity, which was especially injurious to the grass crop. The highest temperature of the season (92.1°) occurred June 16th.

The summer was cool, with a sufficient amount of rainfall for the requirements of crops. September was unusually warm, which favored the growth and maturing of corn.

No killing frost occurred till October 17th. This gave a growing period of 164 days, about a month longer than the average. The first snow fell October 23d. The temperature for November and December was slightly above the normal.

Through the kindness of the officers of the New England Meteorological Society, we are able to publish the rainfall from their Stations. Table A gives the rainfall as recorded during the growing season, at twenty localities in the State. Table B contains a summary of the observations made by the Station at Storrs.

TABLE A.

Rainfall During the Six Months Ending October 31st, 1891.

OBSERVATIONS MADE AT TWENTY LOCALITIES IN THE STATE.

LOCALITY.	OBSERVER.	INCHES PER MONTH.						
		May.	June.	July.	August.	September.	October.	Total.
Falls Village, -	M. H. Dean, - -	1.73	3.62	5.54	3.37	.94	1.60	16.80
Oxford, - -	H. R. Stevens, - -	1.23	3.03	2.88	2.73	1.68	3.84	15.39
Waterbury, -	N. J. Welton,* - -	1.84	1.14	4.17	3.04	1.68	3.04	14.91
New Haven, -	Signal Station,* - -	1.92	1.90	4.52	3.14	3.96	4.62	20.06
Wallingford, -	Mrs. B. F. Harrison,*	2.34	1.39	5.43	3.01	3.84	4.22	20.23
New Britain, -	A. C. Blake, - -	1.70	3.05	3.58	3.64	2.37	2.45	16.79
Newington, -	J. S. Kirkham, - -	1.79	2.25	2.76	3.70	4.64	3.89	19.03
Hartford, - -	Rev. S. Hart,* - -	1.99	2.08	4.41	3.92	4.46	3.57	20.43
Canton, - -	G. J. Case,* - -	2.03	3.11	5.21	4.86	1.46	2.65	19.32
W. Simsbury, -	S. T. Stockwell, -	1.84	2.84	5.11	4.92	1.46	2.45	18.62
Vernon, - -	E. H. Lathrop, - -	1.59	2.16	4.70	2.84	4.74	—	—
S. Manchester, -	K. B. Loomis, - -	1.36	2.08	4.77	4.80	5.47	3.81	22.29
Middletown, -	H. D. A. Ward,* -	1.62	2.70	4.98	3.52	3.46	4.24	20.52
New London, -	Signal Station,* - -	1.42	2.81	3.37	4.99	2.60	6.50	21.69
Lebanon, - -	J. H. Tucker, - -	1.62	2.29	3.22	4.10	5.36	4.85	21.44
Franklin, - -	Clifton Peck, - -	1.65	3,38	4.10	4.74	3.86	5.38	23.11
Mansfield, (Storrs),	E. A. Bailey, - -	2.50	1.84	4.96	3.95	4.08	4.14	21.47
Putnam, - -	Jerome Warren, -	1.62	3.33	3.13	2.85	3.07	3.44	17.44
N. Woodstock, -	L. H. Healey, - -	2.50	2.50	5.35	3.05	3.06	3.60	20.06
Voluntown, -	Rev. E. Dewhurst,* -	2.03	1.97	2.56	5.08	4.10	6.82	22.56
Averages, -	- - - - - -	**1.82**	**2.47**	**4.24**	**3.81**	**3.31**	**3.95**	**19.59**

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* New England Meteorological Society Observer.

TABLE B.

Meteorological Summary for 1891.

OBSERVATIONS MADE AT THE STATION BY E. A. BAILEY.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.	Total.
Highest barometer, - - -	30.54	30.71	30.61	30.58	30.46	30.25	30.39	30.26	30.44	30.61	30.89	30.56	30.53	—
Lowest barometer, - - -	28.86	29.40	29.41	29.14	29.67	29.71	29.76	29.71	29.73	29.60	29.33	29.60	29.49	—
Mean barometer, - - -	30.02	30.08	30.11	29.97	30.02	29.95	30.02	29.99	30.14	30.04	30.15	30.13	30.05	—
Highest temperature, - -	49.2	57.9	54.4	76.7	82.9	92.1	84.9	90.7	85.0	83.5	61.5	59.4	73.2	—
Lowest temperature, - -	7.7	1.9	0.0	20.5	27.9	39.0	47.8	45.6	43.0	20.0	5.4	6.7	22.1	—
Mean temperature, - - -	28.8	29.3	31.9	46.1	54.1	63.9	65.2	68.4	63.7	48.3	38.2	37.0	47.9	—
Relative humidity, - - -	76.9	82.2	73.1	67.9	68.4	75.6	79.7	81.4	85.0	82.2	76.0	—	77.1	—
Total precipitation, - - -	8.52	5.64	4.42	3.51	2.50	1.84	4.96	3.95	4.08	4.14	3.09	4.96	—	51.61
Number of days with precipitation of .01 inches or more,	14	15	12	8	8	10	13	13	7	9	8	12	—	129
Number of clear days, - -	8	10	14	16	13	13	12	8	13	11	13	11	—	142
Number of fair days, - -	12	6	6	5	11	8	8	12	9	10	11	11	—	109
Number of cloudy days, - -	11	12	11	9	7	9	11	11	8	10	6	9	—	114
Total movement of wind in miles,	7,896	7,958	9,393	8,290	6,043	5,132	4,735	4,468	4,591	—	—	9,603	—	—
Maximum velocity, - - -	60	50	48	48	35	25	36	25	26	—	—	55	—	—

THE ACQUISITION OF ATMOSPHERIC NITROGEN BY GROWING PLANTS.

BY CHAS. D. WOODS.

In the Annual Report of the Station for 1889 a detailed account was given, by the Director of the Station and the writer, of the experiments undertaken up to December of that year upon the acquisition of nitrogen from the air by growing plants. Since then about 360 experiments, partly water and partly sand culture, with ten or twelve different species of plants, have been tried. Some of the experiments have been so planned as to grow the plants in an atmosphere containing free nitrogen, but to exclude nitrogen compounds from access to either the roots or the leaves. Most of the experiments, however, have been in continuance of the series reported upon in 1889 and of the same kind, namely, by sand culture in open air, but protected from rain, dew, and frost. The experiments of this latter kind have been continued, not that it is thought necessary to confirm the earlier results, but in the hope of obtaining light upon the kinds of plants that have the power of acquiring nitrogen from the air.

We find, as do other experimenters, that it requires considerable experience to enable us to grow different kinds of plants in sand with success. The treatment that gives good results with one species, we have frequently found to fail with another, and it is only after one or more season's experience that we have learned to grow new species.

The experiments herewith reported upon include only a small part of the work of the Station along this line during the past two years. They are similar to those made by the Station earlier, and add to the knowledge of species of legumes which have been proved to acquire nitrogen from the air, and on this account are now published. The results of other experiments, particularly those upon the growth of plants in an atmosphere freed from all compounds of nitrogen, and collateral investigations, are reserved for future publication.

PLAN OF THE EXPERIMENTS.

The plan of the experiments is practically that which was given in the Report of the Station for 1889, pages 15 to 20, and may be briefly summarized as follows :

The plants were all grown in sea sand, purified by washing and burning. Some of the plants were grown in glass jars and some of them in ordinary six-inch clay pots similar to those used by florists. These latter were freshly burned, and stood upon glass plates. They were used in some of the experiments in which the plants were not supplied with nitrogen in the nutritive solutions, thinking that the porous sides would admit the atmosphere more freely to the roots of the plants than was possible in the case of the glass jars, and that on this account growth might be more normal. The results of the experiments indicate that the plants grew but little better in these than in glass jars, and there was the disadvantage that they used double or treble the amount of water that was required for the plants grown in glass.

Effort was made to grow the plants under conditions as nearly normal as is consistent with a rigid control over the supply of nitrogen. To this end an abundance of plant food, nitrogen excepted, in not too concentrated solutions, room for the development of roots, inoculations with solutions containing the germs which are supplied to produce root tubercles, exposure to sun and air, and protection from wind, rain, dew, and excessive heat, were provided. All of the water used was specially prepared and was nitrogen-free.

An exact account of all the nitrogen supplied the plants, aside from that brought to them from the air, was kept, and at the end of the experiments the nitrogen in the whole plant, as well as that left unused (if any) in the nutritive solution, was determined. The difference between these two amounts shows the loss or gain in nitrogen. A loss indicates decomposition of either the organic nitrogen of the seed of the plant, or of the nitric acid of the nitrates fed, or both. A gain represents nitrogen acquired from the air in excess of any lost from either the organic matter of the seed of the plant or from the nitrates used.*

In the early work a number of plants, four or more, were grown in each pot. It was observed, however, that in only rare cases all of the plants made an equal growth. Frequently only one plant made sufficient growth to indicate that it had gained any considerable quantity of nitrogen. In general, it was found that small plants, so far from gaining, actually lost in nitrogen. Hence the natural inferences* "that the gain of nitrogen was made by the well-developed plants; that the actual gain was larger than the apparent gain; and that this actual gain by the well-developed plants covered the apparent gain on the whole experiment plus enough to make up for any losses from decomposition of seeds of both the vigorous and the weaker plants, from decomposition of nitrates and from other causes. In most of the experiments there was more or less of this difference of growth, and to distribute the gain evenly to all the plants of a single experiment would obviously be erroneous." To avoid this complication, only one plant has been grown in a pot in the experiments herewith reported upon.

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* See discussion of this subject by Atwater and Rockwood, *American Chemical Journal*, 8, p. 327.

The soil infusions used for inoculations were prepared in the same way as described in the Report of 1889, except that in addition to the soil in which plants of the species experimented with had been growing, ground up tubercles from the roots of plants of the same species as those experimented upon were added to the infusions.

The experiments herewith reported upon have been with: Scarlet clover *(Trifolium incarnatum)*. Beans *(Phaesolus nanus)*. Vetch *(Vicia sativa)*. Cow peas *(Dolichos sinensis)*.

SCARLET CLOVER *(TRIFOLIUM INCARNATUM)*.

Three series of experiments were undertaken with scarlet clover. Eighteen plants, one plant in each pot, were grown in ordinary, freshly burned, unglazed clay pots, such as are used by florists. Twelve were grown in glass jars similar to those described in the Report of 1889. Six of these were supplied with nitrogen in the nutritive solution. The other six were grown without.

In former years we had found it difficult to carry clover plants in sand through the first stages of growth. In order to overcome this, the plants were started in pots in ordinary garden soil. Twenty to thirty plants were allowed to grow in four-inch pots until each plant had developed from six to twelve leaves. The ball of earth was then removed from the pot and broken up, and the plants assorted according to size. The largest of the plants,

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* Report of this Station, 1889, pp. 34 and 35.

"first size," had ten or twelve leaves and had made a good root development of about four inches in length. The "second sized" plants had from six to eight leaves, and had made considerably less root development than those of the "first size."

A number of plants of each size were analyzed in order to give a control over the amount of nitrogen they contained when the experiments began. The amount of nitrogen in the "first-sized" plants ranged from 4.7 mg. to 6.9 mg., with an average of 5.7 mg. The "second-sized" plants were considerably smaller. The analyses gave a minimum of 1.9 mg. of nitrogen and a maximum of 3.6 mg., with an average of 2.7 mg. of nitrogen.

The roots were washed free from adhering soil, and while still wet were dipped in sand so that it might adhere and prevent matting together. They were then transplanted into sand in the pots in which they were to be grown, and shaded for a few days. Rough as was this treatment, the plants speedily recovered from the shock of transplanting.

Most of the plants had begun to develop root tubercles before transplanting took place, and this method of starting them had the added advantage of insuring inoculation.

SCARLET CLOVER, IN EARTHEN POTS, WITHOUT NITROGEN.

To each of the plants of this series there was supplied in solution 150 mg. calcium phosphate, 100 mg. magnesium sulphate, 50 mg. calcium chloride, 50 mg. potassium chloride, and 10 mg. ferric chloride. Water was added from time to time as needed. The plants grown in earthen pots required considerably more water than those grown in glass jars, owing to the larger amount of surface exposed for evaporation.

As will be seen in the table on the next page, there was considerable difference in the growth of the plants. Nos. 201, 202, 213, and 214 had "first-sized" plants at the start, but at the end of the experiments there was no more dry matter or nitrogen in these than in some of the others. Plant 204 remained dormant for a very long time, making almost no growth, but later in the season it started up and made considerable growth. All of the plants, as shown by the examination of the roots at the end of the experiment, developed root tubercles. It is probable that the variations in development of the plant, while they may have been caused somewhat by transplanting, are simply in accordance with the fact that different plants from the same kind of seed, and apparently under the same conditions, often develop very differently. All of the plants in this series showed a gain in nitrogen over that contained in the plant at the start. The average gain of the eighteen plants was 37 mg. of nitrogen for each plant, ranging from a gain of 8 mg. of nitrogen in the lowest to 61 mg. in the highest. Many of the plants appeared as vigorous and thrifty as the nitrogen-fed plants in the next series.

The details of the experiments are given in the accompanying table:

TABLE I.

Scarlet Clover Grown in Clay Pots, without Nitrogen in the Nutritive Solution.

REFERENCE NO.*	WEIGHT OF MATURE PLANTS.			NITROGEN STATISTICS.						
				Supplied.			At End of Experiment.			Gain of Nitrogen.
	Tops.	Roots.	Total.	In plant at beginning.	In Nutritive Solution.	Total.	In Plant.	In Nutritive Solution.	Total.	
	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.
201, - - -	2520	1770	4290	6	0	6	67	0	67	61
202, - - -	1000	590	1590	6	0	6	22	0	22	16
203, - - -	1150	1400	2550	3	0	3	20	0	20	17
204, - - -	1720	750	2470	3	0	3	11	0	11	8
205, - - -	1290	870	2160	3	0	3	36	0	36	33
206, - - -	660	700	1360	3	0	3	34	0	34	31
207, - - -	1820	940	2760	3	0	3	46	0	46	43
208, - - -	1770	1590	3360	3	0	3	52	0	52	49
209, - - -	1020	1040	2060	3	0	3	27	0	27	24
210, - - -	770	480	1280	3	0	3	22	0	22	19
211, - - -	1570	1070	2640	3	0	3	37	0	37	34
212, - - -	1650	3270	4920	3	0	3	56	0	56	53
213, - - -	1950	920	2870	6	0	6	51	0	51	45
214, - - -	2620	1250	3870	6	0	6	56	0	56	50
215, - - -	2120	1070	3190	3	0	3	42	0	42	39
216, - - -	1850	3200	5050	3	0	3	55	0	55	52
217, - - -	2040	1990	4030	3	0	3	56	0	56	53
218, - - -	1690	1390	3080	3	0	3	39	0	39	36

* The reference numbers used in this and the following tables are not the original numbers of the experiments, but are in order of those reported upon.

SCARLET CLOVER, IN GLASS POTS, WITH NITROGEN.

Three "first-sized" and three "second-sized" plants, grown in the same way as those used in the preceding series, were transplanted into one-half-gallon glass jars containing three kilograms of sand each. The plants of this series were each supplied with solutions containing 40 mg. of nitrogen in the form of calcium and potassium nitrates, 150 mg. calcium phosphate solution, 10 cc. magnesium sulphate solution, and 1 cc. ferric chloride solution.

The sand (soil) was extracted with water after the plants were through growing, and it was found that the nitrogen of the nitrates supplied had been completely used up.

The accompanying table gives the details of this series of experiments:

TABLE 2.

Scarlet Clover, Grown in Glass Pots. Fed with Nitrogen in the Nutritive Solution.

REFERENCE NO.	WEIGHT OF MATURE PLANTS.			NITROGEN STATISTICS.						
				Supplied.			At End of Experiment.			Gain (or Loss) of Nitrogen.
	Tops.	Roots.	Total.	In Plant at Beginning.	In Nutritive Solution.	Total.	In Plant.	In Nutritive Solution.	Total.	
	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.
219, - - -	5080	2880	7960	6	38	44	89	0	89	45
220, - - -	6300	2830	9130	6	38	44	87	0	87	43
221, - - -	2710	790	3500	6	38	44	45	0	45	1
222, - - -	4280	1920	6200	3	38	41	34	0	34	−7
223, - - -	5270	2330	7600	3	38	41	71	0	71	30
224, - - -	3950	1300	5250	3	38	41	53	0	53	12

Nos. 219, 220, and 221 were "first-sized" plants, and 222, 223, and 224 "second-sized" plants. As will be seen in the table, 219, 220, and 223 made a good growth, while 221, 222, and 224, for some reason, made small growth. Nos. 219, 220, 223, and 224 show a fair gain of nitrogen. No. 221 practically neither gained nor lost, and 222 shows a slight loss.

From the indications in our previous experiments it would seem extremely probable that there was a decomposition of the nitrates, and a consequent loss of the nitrogen supplied to these plants, and that the actual fixation of nitrogen was greater than the figures would imply. That there was any considerable loss of *organic* nitrogen in 222 is extremely doubtful, and the loss indicated doubtless came from the decomposition of the nitrate. The average gain indicated by the four plants is 30 mg. of nitrogen per plant. Including the whole series, the average gain would be 21 mg. of nitrogen per plant.

SCARLET CLOVER, IN GLASS POTS, WITHOUT NITROGEN.

This series of experiments was similar to the first series grown in clay pots, with the difference that the plants were grown in glass instead of clay jars. It differed from the preceding series in having no nitrogen supplied in the nutritive solution. The plants in this series were supplied with the same kinds and amounts of nutritive solution as those of the first series herewith reported. The following table gives the details of the experiments:

TABLE 3.

Scarlet Clover, Grown in Glass Pots, without Nitrogen in the Nutritive Solution.

REFERENCE NO.	WEIGHT OF MATURE PLANTS.			NITROGEN STATISTICS.						
				Supplied.			At End of Experiment.			
	Tops.	Roots.	Total.	In Plant at Beginning.	In Nutritive Solution.	Total.	In Plant.	In Nutritive Solution.	Total.	Gain of Nitrogen.
	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.
225, - - -	720	310	1030	6	0	6	12	0	12	6
226, - - -	1900	1620	3520	6	0	6	31	0	31	25
227, - - -	2090	910	3000	3	0	3	32	0	32	29
228, - - -	730	550	1280	3	0	3	15	0	15	12
229, - - -	2990	780	3770	3	0	3	50	0	50	47
230, - - -	1530	660	2190	3	0	3	27	0	27	24

Nos. 225 and 226 were "first-sized" and 227 to 230 were "second-sized" plants. The growth, as indicated both by weight of plant and nitrogen content, was very uneven. There was in all cases a gain, ranging from 6 mg. to 47 mg. of nitrogen, with an average of 24 mg. for each plant. In only one case (229) was the increase in nitrogen above the average of that found in the series of eighteen plants grown in ordinary clay pots.

That the greater gain in the plants grown in clay pots could have been due to nitrogen obtained from the material of which the pots were made is extremely improbable. The plants grown in clay pots required considerably more water than those grown in glass. The water used in all of the experiments was specially prepared, and was as free from nitrogen as it was practicable to obtain it. The total amount of water supplied each plant could not have contained more than 3 mg. of nitrogen at the outside, and probably contained not much, if any, more than 1 mg. of nitrogen. The pots stood upon plates of glass, and in this way there would be no chance for nitrogenous materials to be absorbed from the bench.

BEANS *(PHAESOLUS NANUS)*, IN GLASS JARS, WITH NITROGEN.

Three experiments were made in gallon glass jars containing 6 kilos of sand. The common small white "pea" bean was used. The seeds contained on the average 3.38 per cent. of nitrogen. The plants were supplied with solutions containing 40 mg. of nitrogen as potassium and calcium nitrates, 300 mg. calcium phosphate solution, 200 mg. magnesium sulphate, and 20 mg. ferric chloride. They were also inoculated with 25 cc. of soil infusion. The soil (sand) contained no nitrogen at the end of the experiment. The results of the experiments are given in the following table:

TABLE 4.

Beans, in Glass Pots. Fed with Nitrogen in the Nutritive Solution.

REFERENCE NO.	WEIGHT OF MATURE PLANTS.			NITROGEN STATISTICS.						
				Supplied.			At End of Experiment.			Gain (or Loss) of Nitrogen.
	Tops.	Roots.	Total.	In Seed.	In Nutritive Solution.	Total.	In Plant.	In Nutritive Solution.	Total.	
	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.
238, - - -	2190	1170	3360	12	40	52	47	0	47	−5
239, - - -	4340	1330	5670	12	40	52	91	0	91	39
240, - - -	2970	1470	4440	12	40	52	75	0	75	23

The plants made fairly good growth. No. 238 ripened 5 perfect and 2 rudimentary seeds. No. 239 ripened 11 perfect seeds, and 240 12 perfect seeds, 4 of which were small. No. 238 had quite a number of large (old?) tubercles, and but very few small (new?) ones. No. 239 had a number of large tubercles and numerous small ones, and 240 had a fair number of fair-sized tubercles No. 240 had the best root development of the three. Nos. 239 and 240 showed a fair gain of nitrogen, while 238 indicated a loss. As in all of the nitrogen-fed experiments, it is probable that more or less of the nitrates given in the nutritive solutions was decomposed and lost to the plant.

VETCH *(VICIA SATIVA)*, IN GLASS POTS, WITH NITROGEN.

Six experiments were made with vetch, in gallon glass jars containing 6 kilos of sand. A large growing Scotch vetch was used. The plants were fed as the last series. There were also given to each plant, at two different times, a total of 40 cc. of soil infusion. There was no nitrogen in the soil (sand) of the plants at the end of the experiment. The results of the experiments are given in the table which follows :

TABLE 5.

Vetch, Grown in Glass Pots. Fed with Nitrogen in the Nutritive Solution.

Reference No.	Weight of Mature Plants.			Nitrogen Statistics.						
				Supplied.			At End of Experiment.			Gain of Nitrogen.
	Tops.	Roots.	Total.	In Seed.	In Nutritive Solution.	Total.	In Plant.	In Nutritive Solution.	Total.	
	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.
241, - - -	5500	1770	7270	9	40	49	130	0	130	81
242, - - -	3120	1620	4740	9	40	49	69	0	69	20
243, - - -	5220	1150	6370	9	40	49	128	0	128	79
244, - - -	2320	220	2540	9	40	49	67	0	67	18
245, - - -	3900	900	4800	9	40	49	97	0	97	48
246, - - -	2420	300	2720	9	40	49	76	0	76	27

All of the plants show considerable gain in nitrogen, although 241, 243, and 245 show decidedly larger gains than do the other three. The plants were so placed during growth that 241, 243, and 245 had more and stronger sunlight than the others. Whether or not this had anything to do with their more vigorous growth is not shown. The plants grew very luxuriantly, and would not have been harvested as soon as they were if it had not been that they were being attacked by red spider.

Each plant had from two to seven branches, and the principal branches of the more vigorous plants were from three to five feet high. At time of harvesting, the plants were either in blossom or else pods were just beginning to form. The average gain of the plants was 47 mg. of nitrogen for each plant, the minimum being a gain of 18 mg. and the maximum of 81 mg. of nitrogen.

VETCH (*VICIA SATIVA*), IN CLAY POTS, WITHOUT NITROGEN.

Twelve experiments were undertaken in this series of experiments, but, owing to the attack of red spider, all but four of the plants were killed when quite young, and the others were badly handicapped. The plants were supplied with solutions containing 150 mg. of calcium phosphate, 100 mg. of magnesium sulphate, 50 mg. of calcium chloride, 50 mg. of potassium chloride, and 10 mg. of ferric chloride. The plants were given, at two different times, a total of 40 cc. of soil infusion. The results of the experiments are given in the table which follows :

TABLE 6.

Vetch, Grown in Clay Pots, without Nitrogen in the Nutritive Solution.

Reference No.	Weight of Mature Plants.			Nitrogen Statistics.						
				Supplied.			At End of Experiment.			Gain of Nitrogen.
	Tops.	Roots.	Total.	In Seed.	In Nutritive Solution.	Total.	In Plant.	In Nutritive Solution.	Total.	
	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.
247, - - -	570	800	1370	9	0	9	29	0	29	20
248, - - -	870	970	1840	9	0	9	31	0	31	22
249, - - -	760	700	1460	9	0	9	28	0	28	19
250, - - -	220	650	870	8	0	8	12	0	12	4

Plant 250 suffered more from red spider than did the others. At the time of harvesting it had not yet budded, but was green and growing at the top. Its leaves were falling. Nos. 248 and 249 were green at the top at the time of harvesting, but had commenced to mature their seeds, 248 having five and 249 six half-grown seeds. No. 247 had two branches, one of which was dead; the other was still growing and had just budded. Notwithstanding this unfavorable condition of growth, these plants all made considerable gains of nitrogen. Nos. 247, 248, and 249 averaged a gain of 20 mg. of nitrogen.

COW PEAS *(DOLICHOS SINENSIS)*, IN GLASS JARS, WITH NITROGEN.

Six experiments were made with cow peas, in two-gallon glass jars containing twelve kilograms of sand. Plants 231 to 234 were supplied with 600 mg. calcium phosphate, 400 mg. magnesium sulphate, 40 mg. ferric chloride, and 40 mg. of nitrogen in the form of calcium and potassium nitrates. Nos. 235 and 237 had in addition to the above 200 mg. calcium chloride and 200 mg. potassium chloride. Each pot was supplied with 25 cc. of soil infusion. There was no nitrogen found in any of the nutritive solutions at the end of the experiment. The table which follows shows the details of the experiments:

TABLE 7.

Cow Peas, Grown in Glass Pots, with Nitrogen in the Nutritive Solution.

Reference No.	Weight of Mature Plants.			Nitrogen Statistics.						
				Supplied.			At End of Experiment.			Gain (or Loss) of Nitrogen.
	Tops.	Roots.	Total.	In Seed.	In Nutritive Solution.	Total.	In Plant.	In Nutritive Solution.	Total.	
	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.
231, - - -	605	316	921	8	40	48	177	0	177	129
232, - - -	465	332	797	9	40	49	138	0	138	89
233, - - -	461	235	696	8	40	48	150	0	150	102
234, - - -	550	227	777	9	40	49	136	0	136	87
235, - - -	635	271	906	9	40	49	162	0	162	113
236, - - -	217	115	332	9	40	49	37	0	37	−12
237, - - -	298	127	425	9	40	49	98	0	98	49

It will be noticed that five of the plants gave large gains of nitrogen, and that one gave about half the average of the others, and in one there was a loss of 12 mg. Nos. 236 and 237 from the start made the poorest growth. At the time of harvest none of the plants were through growing. Two or three of the more advanced ones were beginning to bud.

SUMMARY.

The results of fifty experiments with plants grown in sea-sand, all of which were supplied with minerals needed for their development, and twenty-two of which were in addition provided with small amounts of nitrogen in the form of nitrates, are given in the table which follows :

TABLE 8.

Summary of Pot Experiment Work herewith Reported upon.

KIND OF PLANT.	No. of Experiments.	Nitrogen Supplied in Seed and Nutritive Solution.	GAIN (OR LOSS) OF NITROGEN.		
			Min.	Max.	Average.
		Mg.	Mg.	Mg.	Mg.
Without Nitrogen in Nutritive Solution.					
Scarlet clover,	18	3-6	8	61	37
Scarlet clover,	6	3-6	6	47	24
Vetch,	4	8·9	4	22	16
With Nitrogen in Nutritive Solution.					
Scarlet clover,	6	41-44	−7	45	21
Pea beans,	3	52	−5	39	19
Vetch,	6	49	18	81	46
Cow peas,	7	48-49	−12	129	78

It will be noticed that all of the plants grown without addition of nitrates gained in nitrogen. Three of the plants supplied with nitrates indicate a loss, while the other nineteen gained nitrogen in varying amounts.

As appears from the results in the above table and from those given in previous reports of experiments here, the following species of plants have been found to either provide themselves with nitrogen, where none was supplied except that in the seed, or to gain nitrogen in excess of that supplied in seed and nutritive solution : Peas, cow peas, beans, vetch, alfalfa, and scarlet clover.

All the legumes and no other plants with which satisfactory trials have been made, have proven capable of acquiring large quantities of nitrogen from the air. The gain has occurred where root tubercles were developed, and without them there has been no gain of any account.

SPECIAL NITROGEN EXPERIMENT ON GRASS.

BY CHAS. D. WOODS AND C. S. PHELPS.

The hay crop is to-day one of the most important and profitable farm crops in New England. It is the chief food of all live stock, and through their products becomes the chief food of man. The grass family, as a whole, contains more plants of value to man than any other order of plants. The introduction of improved machinery has greatly lessened the cost of hay production; and the use of concentrated grain feeds in connection with the coarser grasses and other cheaper fodder plants, leaves the better grades of hay to supply a ready home market at paying prices.

Most farmers depend almost entirely upon the use of stable manures in the production of this crop, preferring to use commercial fertilizers, if at all, on the hoed crops. Few, if any, of our ordinary farm crops make quicker and more paying response to commercial fertilizers than grass. It is frequently the case in growing farm crops, that the best results are obtained by the use of stable manures, together with some commercial form of plant-food that serves to meet the special requirements of the crop or soil. Grass responds readily to soluble nitrogen compounds. A medium heavy application of stable manure in the fall or winter, followed by a light application of nitrate of soda or sulphate of ammonia about the first of May, is often found to give the most paying results on grass.

The Special Nitrogen Experiments on Grass reported upon in the Report of this Station for 1890 have been continued during the present year. It is planned to continue these experiments through a series of years, applying the same fertilizers to the same plots. It is to be borne in mind that conclusions based upon two seasons' trials must not be made general.

PURPOSE OF THE EXPERIMENTS.

The experiments were undertaken for the purpose of studying the effect of nitrogenous fertilizers upon grass as shown by :

1. The yield of grass and hay per acre.
2. The financial results.
3. The chemical composition and feeding value of the crop.

DETAILS OF THE EXPERIMENT.

The experiment was similar to the special nitrogen experiments with corn described in the Annual Reports of the Station.* It will be observed that plots 1 to 5, on which nitrogen, phosphoric acid, and potash are applied singly and two by two, and also plot 6 with mixed minerals, were omitted from these experiments. These soil test plots were omitted for lack of room in the field, and not because interesting results might not have been expected from them. It was with a good deal of reluctance that plot 6, with mixed minerals, was omitted, as it is very desirable in the special nitrogen experiments to have a mixed mineral plot on either side of the nitrogenous groups.

The general plan of the experiments was to apply the same quantities of mineral fertilizers (potash and phosphoric acid) to all the plots, and to add nitrogen to all except two at the rate of 25, 50, and 75 pounds per acre. The whole experiment as planned includes nitrogen in the three forms: nitrates, ammonia salts, and organic nitrogen. The parts of the field on which are the plots to which nitrogen as organic nitrogen (dried blood) was applied had a light application of compost in the fall of 1888, and as this appeared to affect the crop in 1890 and 1891, these plots are not included in this Report.

The field has a gentle slope to the south and southwest, but not enough to occasion the washing of fertilizers from one plot to another. The plots contained one-eighth acre each, and were laid out so as to conform to the slope of the field. They are 302.5 feet long by 18 feet wide, with unfertilized strips 3 feet wide between each plot.

The soil is a medium heavy loam, and the sub-soil is slightly clayey and adhesive. The soil was in a comparatively low state of fertility, as is shown by the yield on the unmanured plots. The land is not quickly affected by drought, and appears to retain fertilizers readily. The natural drainage is good.

The field has been in grass for several years, without the application of fertilizers of any kind until 1890, with the exception noted above in the case of the dried-blood plots. The principal grasses growing on the field are timothy, redtop, and Kentucky blue grass, with a slight admixture of clover and some weeds.

The plan of the experimental field is given on the next page.

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* See Reports of this Station, 1888, pages 72 to 89; 1889, pages 103 to 119; and 1890, pages 71 to 74.

SPECIAL NITROGEN EXPERIMENT ON GRASS.

PLAN OF EXPERIMENTAL FIELD.

Each plot one-eighth acre. Unmanured strips separate the plots. The weight of fertilizers and of nitrogen are given in *pounds per acre.*

PLOT 0.	Nothing.		
PLOT 7.	Mixed Minerals, as 6*a*, Nitrate of Soda, -	480 lbs. 160 lbs.	Nitrogen, - 25 lbs.
PLOT 8.	Mixed Minerals, as 6*a*, Nitrate of Soda, -	480 lbs. 320 lbs.	Nitrogen, - 50 lbs.
PLOT 9.	Mixed Minerals, as 6*a*, Nitrate of Soda, -	480 lbs. 480 lbs.	Nitrogen, - 75 lbs.
PLOT 6*a*.	Dissolved Bone-black, Muriate of Potash,	320 lbs. 160 lbs.	"Mixed Minerals."
PLOT 10.	Mixed Minerals, as 6*a*, Sulphate of Ammonia,	480 lbs. 120 lbs.	Nitrogen, - 25 lbs.
PLOT 11.	Mixed Minerals, as 6*a*, Sulphate of Ammonia,	480 lbs. 240 lbs.	Nitrogen, - 50 lbs.
PLOT 12.	Mixed Minerals, as 6*a*, Sulphate of Ammonia,	480 lbs. 360 lbs.	Nitrogen, - 75 lbs.
PLOT 00.	Nothing.		
PLOT 6*b*.	Mixed Minerals, as 6*a*,	480 lbs.	Phosp'c Acid, 54 lbs. Potash, - 82 lbs.

NOTES DURING GROWTH.

Season of 1890.—The fertilizers were applied April 29th. On May 1st, there was a rainfall of .15 inches, and from the 4th to the 6th of May, the rainfall amounted to 1.8 inches. This heavy fall of rain did not produce any apparent surface flow on the field.

Notes taken one week from the date of application show that there was considerable response to the fertilizers on all the plots supplied with nitrogen, while the plots having mixed minerals alone showed very little advance over the unmanured plots. In fact, the mineral plots gained but little over the unmanured plots until two or three weeks after the fertilizers were applied.

On June 10th, it was noted that the best growth was upon the plots which had received the most nitrogen, and that very little difference in appearance could be observed between the plots which had nitrate of soda and those which had an equal amount of nitrogen as sulphate of ammonia. At this date, the blue grass was in full bloom, while the timothy heads were only one-fourth to one-third grown. The crop on the mixed mineral plots appeared to be about one-third heavier than that upon the nothing plots, and the proportion of clover was much greater than appeared on the plots to which nitrogen had been applied.

At the time of cutting, June 25th, the principal grasses were timothy and redtop. The timothy was beginning to blossom. The heads of the redtop we about three-fourths grown. The blue grass was not as noticeable as it had been earlier, and had pretty generally seeded, and on the unmanured plots was dry and woody. Red and white clover was a little past full bloom. There was a large proportion of clover, especially of white clover, on the mixed mineral plots. The proportion of clover was greater on the plots of the sulphate group (10, 11, and 12) than it was on those of the nitrate group (7, 8, and 9). The grass on the plot directly entering into the experiment was cut June 25th. A Eureka machine (center cut) was used, and the grass on the unfertilized strips between the plots was left standing until the crop on the plots was harvested. The hay was weighed aud put in the barn the afternoon of the 26th.

Season of 1889.—The fertilizer was applied May 1st. On the 3d there was a rain-fall of .15 inches.

Notes taken May 8th show there were but little differences between the fertilized plots. The proportion of clover was much less than in 1890. There was quite a large proportion of clover on plot 6*b*; the other fertilized plots showed but little.

The first differences in growth on the plots supplied with different fertilizers were noticed May 14th. On May 15th and 16th there was a heavy rain, followed by a rapid growth on all the plots.

June 1st the following notes were taken: The proportion of fine grasses greater than in 1890. The Kentucky blue grass coming into bloom on all the plots. The growth on the sulphate of ammonia plots (10, 11, and 12) is heavier and more advanced than on the nitrate of soda plots (7, 8, and 9).

All the plots made slow growth during the first half of June, and at the middle of the month the Kentucky blue grass was beginning to dry and turn brown.

On June 23d, it was noted that the growth on all the plots was much improved by the heavy rain of the 18th and 19th. A dense bottom growth and an increase in the proportion of timothy were especially noted.

At the time of cutting, June 29th, the principal grasses were timothy, redtop, and blue grass. The blue grass had generally seeded, and had become dry and woody on all the plots. The timothy was coming into bloom. The redtop was nearly full grown, and much of it in bloom. With the exception of plot 6*b*, the proportion of clover to the other grasses was very small. The grass on the nitrate of soda plots (7, 8, and 9) appeared to have made a little heavier growth and to contain a larger proportion of timothy than that of the sulphate of ammonia plots (10, 11, and 12). The proportion of fine grasses, and especially blue grass, was greater on all the plots than in 1890. The crop from all the plots was weighed and put into the barn between 2 and 4:30 P. M., June 24th.

The grass on the unmanured strips between the plots was cut and removed several days before the crop on the plots was harvested.

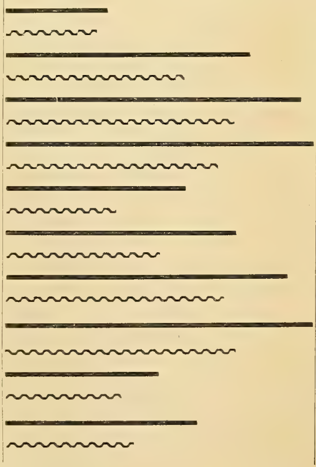
TABLE 9.

SPECIAL NITROGEN EXPERIMENT ON GRASS.

Yield of Hay per Acre.

Yield in 1890 indicated by ▬▬▬, weights in Roman.
Yield in 1891 indicated by ∿∿∿∿, weights in Fullface.

No. of Plot.	FERTILIZERS.		YIELD PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Lbs.
0	Nothing, - -	—		1920
				1722
7	Mixed Minerals, -	480		4759
	Nitrate of Soda, -	160		**3394**
8	Mixed Minerals, -	480		5874
	Nitrate of Soda, -	320		**4505**
9	Mixed Minerals, -	480		6032
	Nitrate of Soda, -	480		**4282**
6*a*	Ds. Bone-bk. Mx.	320		3353
	Mur. Potash, Min.	160		**2201**
10	Mixed Minerals, -	480		4672
	Sulp. of Ammonia,	120		**2935**
11	Mixed Minerals, -	480		5716
	Sulp. of Ammonia,	240		**3898**
12	Mixed Minerals, -	480		6056
	Sulp. of Ammonia,	360		**4215**
00	Nothing, - -	—		2819
				1668
6*b*	Mixed Minerals, -	480		3604
				2147



In table 9, which precedes, the comparative yields per acre are shown for both the years 1890 and 1891. The field weights are calculated to a uniform water basis of 11 per cent. (89 per cent. dry matter). The yields obtained on the plots having no manure (0 and 00) were more uniform in 1891 than in 1890. The comparative uniformity of the yield from the unfertilized plots, and those to which mixed minerals were applied, would seem to indicate a fairly uniform soil. Notes taken during the growing season in 1890 show that the proportion of clover, especially white clover, was increased on both the mineral plots, while in 1891 6*b* alone showed a decided increase in the amount of clover. Hence, part of the increase in yield on the mixed mineral plots above those to which no manure was applied was due to clover. The inference, therefore, is that in these cases the grasses did not respond in a marked degree to mineral fertilizers. The presence of available nitrogen seems to have been necessary to produce any very decided increase in the yield of the ordinary grasses.

In 1890, the yield on the plots supplied with nitrogen appeared to depend upon the quantity of nitrogen supplied more than upon the form in which it was applied. In that season the yield was practically the same on all the plots supplied with like amounts of nitrogen, whether from nitrate of soda or sulphate of ammonia.

In 1891, the largest yield was from the plots supplied with fifty pounds of nitrogen in the form of nitrate of soda. The yield from plots 7 and 8, supplied with nitrate of soda, was greater than that of the corresponding plots, 10 and 11, supplied with sulphate of ammonia. The yield from the plots having 75 pounds of nitrogen (9 and 12) was practically the same with nitrate of soda as with sulphate of ammonia. The marked falling off in yield in 1891 from that of 1890, especially with the fertilized plots, is undoubtedly due to the drought in the early part of June, at which time grasses usually make their best growth. On this account the season of 1891 has not been a favorable one for experiments of this character.

The yield from the sulphate of ammonia plot, to which nitrogen was applied at the rate of 75 pounds per acre, was a trifle larger than from that to which it was applied at the rate of 50 pounds. On the nitrate of soda plots the yield was less with 75 pounds of nitrogen than with fifty.

FINANCIAL RESULTS.

Table 10, which follows, shows the cost of the fertilizers, the value of the increased yield, and the gain or loss per acre.

TABLE 10.

SPECIAL NITROGEN EXPERIMENT ON GRASS.

Weight and Cost of Fertilizers per Acre, Increase of Crop over that of the Nothing Plots, Value of the Increase, and Gain or Loss (–) per Acre.

Results for 1890 in Roman, and for 1891 in Fullface.

No of Plot.	FERTILIZERS.	Weight of Fertilizers.	Year.	Cost of Fertilizers.	Total Crop (11 % of Water).	Increase over Nothing Plots.	Value of Increase.	Net Profit or Loss (–).
		Lbs.		$	Lbs.	Lbs.	$	$
0	Nothing, - - - -	—	1890	—	1920	—	—	—
			1891	—	**1722**	—	—	—
7	Mixed Minerals, as No. 6, -	480	1890	12.00	4759	2389	14.33	2.37
	Nit. of Soda, 25 lbs. Nitrogen,	160	**1891**	**12.00**	**3394**	**1699**	**12.74**	**.74**
8	Mixed Minerals, as No. 6, -	480	1890	15.96	5874	3504	21.02	5.10
	Nit. of Soda, 50 lbs. Nitrogen,	320	**1891**	**15.96**	**4505**	**2810**	**21.08**	**5.12**
9	Mixed Minerals, as No. 6, -	480	1890	19.92	6032	3662	21.97	2.09
	Nit. of Soda, 75 lbs. Nitrogen,	480	**1891**	**19.92**	**4282**	**2587**	**19.40**	**–.52**
6*a*	Dissolved Bone-black, Mix'd	320	1890	8.00	3353	983	5.90	–2.10
	Muriate of Potash, Mins.	160	**1891**	**8.00**	**2201**	**506**	**3.80**	**–4.20**
10	Mixed Minerals, as No. 6, -	480	1890	12.44	4672	2302	13.81	1.37
	Sulp. of Am., 25 lbs. Nitrogen,	120	**1891**	**12.44**	**2935**	**1240**	**9.30**	**–3.14**
11	Mixed Minerals, as No. 6, -	480	1890	16.88	5716	3346	20.08	3.20
	Sulp. of Am., 50 lbs. Nitrogen,	240	**1891**	**16.88**	**3898**	**2203**	**16.52**	**–.36**
12	Mixed Minerals, as No. 6, -	480	1890	21.32	6056	3686	22.12	.80
	Sulp. of Am., 75 lbs. Nitrogen,	360	**1891**	**21.32**	**4215**	**2520**	**18.90**	**–2.42**
00	Nothing, - - - -	—	1890	—	2819	—	—	—
			1891	—	**1668**	—	—	—
6*b*	Mixed Minerals, as No. 6, -	480	1890	8.00	3604	1234	7.40	–.60
			1891	**8.00**	**2147**	**452**	**3.39**	**–4.61**

The cost of the fertilizers in each case is taken at rates in ton lots for the ingredients, dissolved bone-black, potash salts, etc. Two dollars per ton are added to cover the cost of mixing, freight, etc. In the experiment of 1890 the hay was valued at $12 per ton, and in 1891 at $15 per ton. In 1890 there was a fair return from the application of fertilizers in all cases where nitrogen entered into the mixture. In 1891 there was a small gain with nitrate of soda, when applied at the rate of 25 pounds of nitrogen, and when applied at the rate of 50 pounds per acre the gain was as great as in 1891. With these exceptions, all of the fertilizers were applied in 1891 at a financial loss. In both years the mixed minerals were applied by themselves at a loss.

In the experiments of 1890, there seemed to have been no loss in the application of the nitrate of soda in large quantities, as the best yield was obtained at the rate of 320 pounds (75 pounds nitrogen), but in 1891 the case seems to have been different, as the yield was smaller from the plots supplied with 75 pounds of nitrogen than that with 50.

CHEMICAL COMPOSITION OF CROP.

Immediately preceding the field-weighings of the crop, samples, representing as nearly as practicable the hay of each plot, were taken for analysis. The samples were prepared for analysis in the usual way, and the analyses were made by the methods adopted by the Association of Official Agricultural Chemists.

TABLE 11.

SPECIAL NITROGEN EXPERIMENT ON GRASS.

Proximate Composition of Hay, Calculated on Water-free Substance.

Results for 1890 in Roman, and for 1891 in Fullface.

No. of Plot.	FERTILIZERS.	Year.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Water at Time of Harvest.
			%	%	%	%	%	%
0	Nothing, - - - - -	1890	7.31	3.63	52.86	31.23	4.97	21.9
		1891	**6.44**	**3.38**	**54.58**	**31.06**	**4.54**	**25.2**
7	Mixed Minerals, as No. 6, - -	1890	8.37	3.71	48.83	33.54	5.55	26.9
	Nitrate of Soda, 25 lbs. Nitrogen,	**1891**	**6.94**	**3.66**	**52.28**	**32.01**	**5.11**	**32.4**
8	Mixed Minerals, as No. 6, - -	1890	8.09	3.49	48.69	34.61	5.12	29.1
	Nitrate of Soda, 50 lbs. Nitrogen,	**1891**	**8.75**	**4.08**	**49.15**	**32.69**	**5.33**	**31.7**
9	Mixed Minerals, as No. 6, - -	1890	9.19	3.51	47.59	34.55	5.16	27.0
	Nitrate of Soda, 75 lbs. Nitrogen,	**1891**	**9.00**	**4.29**	**49.98**	**31.40**	**5.33**	**33.0**
6*a*	Dissolved Bone-black, Mixed	1890	8.23	3.21	49.96	32.78	5.82	25.7
	Muriate of Potash, Minerals.	**1891**	**6.63**	**3.45**	**53.63**	**31.10**	**5.19**	**26.8**
10	Mixed Minerals, as No. 6, - -	1890	7.55	3.51	49.39	34.20	5.35	23.7
	Sulp. of Am., 25 lbs. Nitrogen, -	**1891**	**7.38**	**3.86**	**51.61**	**31.87**	**5.28**	**32.6**
11	Mixed Minerals, as No. 6, - -	1890	8.36	4.35	48.11	33.98	5.20	23.8
	Sulp. of Am., 50 lbs. Nitrogen, -	**1891**	**8.75**	**4.08**	**49.73**	**31.66**	**5.78**	**29.8**
12	Mixed Minerals, as No. 6, - -	1890	9.17	3.66	48.39	33.68	5.10	22.0
	Sulp. of Am., 75 lbs. Nitrogen, -	**1891**	**9.94**	**4.30**	**49.55**	**30.61**	**5.60**	**32.7**
00	Nothing, - - - - -	1890	7.39	3.88	52.34	31.32	5.07	24.3
		1891	**7.31**	**3.94**	**52.01**	**31.72**	**5.02**	**22.1**
6*b*	Dissolved Bone-black, Mixed	1890	8.23	3.59	50.25	32.09	5.84	20.7
	Muriate of Potash, Minerals.	**1891**	**7.31**	**4.03**	**51.13**	**31.84**	**5.69**	**22.6**

Table 11, on the preceding page, gives the results of the analyses, calculated on water-free substance, and in the last column there is given the percentages of water in the sample at the time of putting the hay into the barn.

It will be noticed that in 1890 the percentages of water varied from 21 to 29 per cent., and in 1891 from 22 to 33 per cent. In the yield per acre, as given in tables 9 and 10, this variation in water content has been overcome by calculating the yield per acre to a uniform water basis. If this had not been done, the apparent results of the experiment would have been quite different from those given in the tables, since the varying percentages of water make very great differences in the field weights of the crop. For instance, in 1890, plot 9 gave a yield as indicated by the field weight of 7344 pounds, and plot 12 of 6904 pounds, but when calculated to a uniform water content, the results are nearly identical, being 5357 pounds in case of plot 9 and 5383 pounds in case of plot 12. This case, which is not an extreme instance in this experiment, illustrates the ease with which false deductions may be drawn from the field weighings, when the water content of the crop is unknown.

If it is assumed, as it has been in the tables indicating the yields per acre, that average hay has 11 per cent. of water, it will be seen that there is a very great shrinkage in the weight of hay at time of harvest from what it would weigh in mid-winter. In the case of these experiments the shrinkage would be from about 200 to nearly 500 pounds per ton. The amount of shrinkage would of course depend, in a great degree, upon the maturity of the grass when cut and the dryness of the hay when put into the barn, as well as upon the place of storage, etc.

The percentages of protein in the crop from the nothing plots in 1890 were practically alike, and this was also true of the protein in the crop from the mixed mineral plots. But in 1891 the percentages of protein in the crop of the o plot was nearly one per cent. less than from the oo plot, and the protein in the crop from plot 6*a* was .7 per cent. less than that from plot 6*b*. This is probably due to the fact that in 1891 there was but very little clover on the part of the field containing plot o, but at the end of the field which contained the mixed mineral plot, 6*b*, there was considerable clover.

The lower percentages of protein in 1891, in the crop from plots o, 7, 6*a*, and 6*b*, were doubtless due to the fact that there was less clover on these plots in 1891 than in 1890. Because of the comparative absence of clover in 1891 from plots 7, 8, 9, 10, 11, and 12, the effect of nitrogenous fertilizers upon the percentages of protein in the grass grown was more strikingly shown than in that from the same plots in 1890.

In table 12 there is given the yield of dry matter and the proximate constituents per acre for both 1890 and 1891. With the exception of plot 9, in which the yield per acre is considerably less than from plot 8, it will be observed that the pounds of protein removed in the crop increased much faster than the dry matter per acre. Of course, this was to have been expected from the results of the chemical analyses given in the preceding table.

TABLE 12.

SPECIAL NITROGEN EXPERIMENT ON GRASS.

Water-free Substance and Proximate Ingredients per Acre.

Results for 1890 in Roman, and for 1891 in Fullface.

No. of Plot.	FERTILIZERS.	Year.	Water-free Substance at Harvest.	Protein.	Crude Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0	Nothing, - - - - - -	1890	1707	125	62	902	533	85
		1891	**1531**	**99**	**52**	**836**	**475**	**69**
7	Mixed Minerals, as No. 6, - -	1890	4230	354	157	2065	1419	235
	Nitrate of Soda, 25 lbs. Nitrogen, -	**1891**	**3017**	**209**	**110**	**1578**	**966**	**154**
8	Mixed Minerals, as No. 6, - -	1890	5221	423	182	2542	1807	267
	Nitrate of Soda, 50 lbs. Nitrogen, -	**1891**	**4004**	**350**	**163**	**1969**	**1309**	**213**
9	Mixed Minerals, as No. 6, - -	1890	5357	492	188	2550	1850	277
	Nitrate of Soda, 75 lbs. Nitrogen, -	**1891**	**3806**	**342**	**163**	**1903**	**1195**	**203**
6*a*	Dissolved Bone-black, } Mixed	1890	2989	246	96	1493	980	174
	Muriate of Potash, } Minerals.	**1891**	**1956**	**130**	**67**	**1049**	**608**	**102**
10	Mixed Minerals, as No. 6, - -	1890	4153	314	146	2051	1420	222
	Sulp. of Ammonia, 25 lbs. Nitrogen,	**1891**	**2609**	**192**	**101**	**1347**	**831**	**138**
11	Mixed Minerals, as No. 6, - -	1890	5081	425	222	2444	1726	264
	Sulp. of Ammonia, 50 lbs. Nitrogen,	**1891**	**3465**	**303**	**141**	**1724**	**1097**	**200**
12	Mixed Minerals, as No. 6, - -	1890	5383	494	197	2605	1813	274
	Sulp. of Ammonia, 75 lbs. Nitrogen,	**1891**	**3747**	**372**	**161**	**1857**	**1147**	**210**
00	Nothing, - - - - - -	1890	2505	185	97	1311	785	127
		1891	**1483**	**108**	**58**	**772**	**470**	**75**
6*b*	Dissolved Bone-black, } Mixed	1890	3204	264	**115**	1610	1028	187
	Muriate of Potash, } Minerals.	**1891**	**1908**	**139**	**77**	**976**	**607**	**109**

Theoretically, the addition of 25 pounds of nitrogen in the fertilizer should have increased the amount of protein per acre 163 pounds, if the grasses had been enabled to utilize, and convert all of the nitrogen into protein compounds. The largest increase in protein that resulted from the addition of 25 pounds of nitrogen was 141 pounds, and in the case of plot 9 in 1891, so far from there being an increase in protein from the addition of 25 pounds of nitrogen, there was a decrease of 8 pounds. This would seem to imply that, even in the most favorable of the results of this experiment, part of the nitrogen applied in the fertilizer was lost to the plants. The largest increase in nitrogen of the crop from the addition of 25 pounds of nitrogen in the fertilizer was 22.6 pounds, and in the case of plot 9 in 1890 there was 1 pound less of nitrogen in the crop to which the extra 25 pounds of nitrogen were added than in that of plot 8.

SUMMARY.

The object of this experiment is to observe the effects of nitrogenous fertilizers upon grass as shown by the yield per acre, the financial results, and the chemical composition of the hay. It is similar to the special nitrogen experiments upon corn that have been conducted by the Station in previous years. The plots contained one-eighth acre each, and were separated from each other by unfertilized strips. The field had been in grass for several years, and the soil was considerably reduced in fertility. Mineral fertilizers (phosphoric acid and potash) were applied to all the plots except two, which were left unmanured. To the manured plots, except two, nitrogen (in the form of nitrate of soda or sulphate of ammonia) was applied, at the rate of 25, 50, and 75 pounds per acre. The experiment has been carried through two years, and is to be continued.

THE RESULTS.

The addition of mineral fertilizers in 1890 increased the yield of clover very markedly, and somewhat so in 1891, but did not seem to increase very decidedly the yield of grass.

The yield of hay in 1890 increased with the quantity of nitrogen supplied, whether it was applied in the form of nitrate of soda or sulphate of ammonia. In 1891, the largest yield was obtained from the plot on which nitrate of soda was applied at the rate of 50 pounds per acre.

The mineral fertilizers in both years, when used alone, were applied at a financial loss.

The best financial returns, a gain of $5 per acre, were obtained in both seasons from the use per acre of 320 pounds of nitrate of soda

(50 pounds of nitrogen) in addition to the mixed minerals. The drought in the early part of June made the season of 1891 an unfavorable one for fertilizer experiments on grasses.

The application of nitrogenous fertilizers increased the percentages of protein (nitrogen multiplied by 6.25) in the grasses, and somewhat in proportion to the amounts applied. This is in accord with observations made by the Station upon the relation of the protein in maize, corn, and stover, to the nitrogen applied in the fertilizers. Since protein, which makes blood, bone, muscle, and milk, is a most important ingredient of food, and is apt to be deficient in our feeding stuffs, this increase of protein from the use of nitrogen is an important matter.

The increase in the amount of nitrogen in the crop did not equal the increased amount of nitrogen supplied in the fertilizers, implying that the plants were not able to avail themselves of all the nitrogen supplied.

PRACTICAL CONCLUSIONS.

Grasses differ from many other crops in the readiness with which they respond to nitrogenous fertilizers. While clover and the other legumes may be called "nitrogen gatherers," the grasses, such as timothy, redtop, etc., must be classed with the "nitrogen consumers." Fertilizers containing potash or phosphoric acid without available nitrogen, are usually much less effective for grass than if they have nitrogen in addition. It would seem desirable that fertilizers for grass lands should, therefore, contain considerable quantities of nitrogen in a readily available form. Their use has the two-fold advantage of increasing the total yield and the feeding value of the crop. The extent to which hay is used as a fodder indicates an important place for commercial fertilizers in its production.

FOOD INVESTIGATIONS.

BY W. O. ATWATER AND CHAS. D. WOODS.

TITLES OF CHAPTERS.

1. ***Introductory Statements.***
2. ***The Composition of Food Materials.***
3. ***A Study of Dietaries.***
4. ***American and European Dietaries and Dietary Standards.***
5. ***Results and Methods of Food Investigations.***
6. ***The Chemistry and Economy of Foods.***

INTRODUCTORY STATEMENTS.

BY W. O. ATWATER.

In the following series of chapters are briefly set forth some of the results of investigations of the chemistry and economy of foods which have been made by the writer and others associated with him, mostly in the chemical laboratory of Wesleyan University, at different times during a period of now more than twelve years. Such of the results as are ready for publication, but have not been previously put in print, are given here in sufficient detail to show their import. From those which have already appeared, so much is recapitulated as may, when united with the results of research elsewhere, serve to establish certain principles of the science of food and nutrition which have a direct bearing upon hygiene, and upon domestic and national economy, and which the writer believes to be worthy of more consideration than they have thus far received, especially in the United States. A few words explaining what the investigations are and how they have come to be made, may not be out of place.

The inquiry had its inception in studies of the chemistry of fish. For these, assistance was provided through the kindly interest of Prof. S. F. Baird, in accordance with a usage frequently followed by him as head of the Smithsonian Institution, the United States National Museum, and the United States Fish Commission. Through his agency, small sums were appropriated from time to time, between the years 1877 and 1882, toward defraying the expenses for apparatus and labor of assistants. To the help thus given, more was added by private persons, and analyses were made of specimens of the flesh and other organs of sixty-four species of American marine and fresh-water fishes and invertebrates.

The information which these studies brought regarding the food values of fish emphasized the need of studying other materials used for food. It has been a practice among statisticians, economists, and not infrequently among physiologists and chemists as well, in estimating the nutritive values of food materials, to assume certain figures for the average composition of materials of different classes, as beef, mutton, fish, milk, flour, and so on. This is, of course, a rough statistical method. In Europe, and especially in Germany, investigations in the laboratories of universities, experiment stations, and other institutions of research, have already led to the accumulation of extensive data regarding the chemical composition and nutritive values of the materials in use there, but outside of the analyses of fish just referred to as made in this laboratory, and some of milk, butter, and cheese conducted elsewhere, almost none of animal, and very few of vegetable, foods had been made on this side of the Atlantic Ocean.

It happened that the writer was called upon to prepare plans for specimens, labels, and other illustrative materials for the Food Collection of the United States National Museum. For this purpose it was desirable, indeed logically necessary, to illustrate the fundamental principles of food economy. To this end, information regarding the chemical composition of our common food materials was indispensable. The National Museum is essentially an educational institution. It is visited by many thousands of people. A number of its collections, including that of foods, are exhibited from time to time at various places in the country. Its teachings are accepted as authoritative. The economy of food is a subject which is rapidly becoming to be recognized by thoughtful people in the United States. To base the statistics of chemical composition of American food products upon European analyses would be hardly appropriate, even if it were certain that the products there and here were nearly alike in composition. But the available knowledge regarding our own products sufficed to scarcely more than show that they differ considerably from the European ones, and that among themselves they are extremely variable.

An adequate series of investigations of American food products would be a very large undertaking. Its necessity was not understood. The only thing to do was to make a beginning, and trust that, as the results should appear, help for further inquiry would be found. Accordingly, not far from one hundred specimens of meat and other animal food materials were analyzed. The results of these investigations, taken in connection with some studies of dietaries which followed, implied that our meats contain much more fat than the needs of the consumers in the country for nutrition call for, or the demands of our home or foreign markets warrant; that, in other words, there is in the present method of meat production, which is so important a factor of agriculture in the United States, a serious economic error. To get more light upon this subject, another series of analyses were made as a part of the chemical work of the Experiment Station. Finally, as a part of a study of dietaries carried out in connection with the United States Department of Labor, a third series of analyses were performed. Until now none of these three series have been printed in detail, though the results of the earlier ones have been incorporated in tables of composition of food materials. They are all given in the chapter on "The Composition of Food Materials" herewith, and are used in the summarized tables in that chapter and in the shorter tables of the chapter on "The Chemistry and Economy of Food."

The further the investigations of fish, above referred to, were prosecuted, the more manifest did the desirability of studies of the chemical constitution of the compounds of the flesh of fish, and other animals, and their digestibility, become. Through the favor of the Board of Trustees of Wesleyan University, the writer was granted a leave of absence for the academic year 1882–3, which time was spent in the study of these and kindred subjects in Europe. For the experiments upon the digestibility of the flesh of fish, the very superior facilities of the physiological laboratory of the University of Munich, including the services of specially trained laboratory servants, were placed at his disposal by the Director of the laboratory, Prof. C. von Voit. A series of experiments were made with men and a dog, the results of which confirmed the natural supposition that the flesh of the leaner kinds of fish, like the leaner kinds of meat, are very readily and completely digestible. For an investigation of the constitution of the muscular tissue of fish, as compared with that of mammals, the facilities of the physiological laboratory of the University of Heidelberg were offered with similar hospitality by the Director, Prof. W. Kühne. The investigations there begun have since been continued in Middletown, but are not yet completed. They suffice, however, to bring out very marked similarities, and scarcely any very important differences between the flesh of the fish and the other flesh (beef) examined.

One outcome of later experimental inquiry in physiological chemistry, is to explain more clearly than had before been done, the use of food as fuel to supply the body with heat to keep it warm, and muscular strength for its work. It appears that the potential energy of the nutritive compounds, albumen, fat, starch, etc., or, in other words, their heats of combustion, as determined by the calorimeter, may, with proper corrections, be taken as a measure of their food value. With the aid of a gift from the research fund of the American Association for the Advancement of Science, supplemented by another from C. W. Smiley, Esq., a graduate of the class of 1874, of Wesleyan University, a series of calorimeter investigations have been undertaken in this laboratory. The results obtained previous to Jan. 1, 1891, were published in an article by Mr. H. B. Gibson, in the Report of the Experiment Station for 1890.

In connection with the Massachusetts Bureau of Statistics of Labor, a series of studies of the quantities of constituents of the food used in somewhat over thirty dietaries of working people in Massachusetts and Canada was made in 1886. At the same time, and later, some half dozen dietaries of college students and other people in Middletown were examined. During the past year, studies in the same direction, but by more detailed and thorough methods, have been carried on in connection with the United States Department of Labor. The results of these studies, and of comparisons of them with results of investigations in Europe, are given in the chapter on a Study of Dietaries, and in that on American and European Dietaries and Dietary Standards.

Another chapter summarizes certain conclusions to which these investigations and the collateral studies have led, and indicates certain lines of inquiry which, in the writer's judgment, demand earnest and thorough study. It will be seen that they have to do, not only with chemical and physiological, but, also, with the economic and agricultural bearings of the subject.

Finally, as the investigations above referred to are rather abstruse and technical, an attempt at a popular exposition of some of the principles and their practical application, is made in the final chapter of this monograph.

Articles describing the investigations above cited, have appeared in scientific and technical publications, as follows:

I. On the chemistry and the nutritive value of fish.

Reports of the United States Commission of Fish and Fisheries, 1880 and 1883. [The details of the investigation are given in a monograph now in press, and to be published by the United States Fish Commission.]

Berichte der Deutschen Chemischen Gesellschaft, XVI., pp. 1839–1846. *American Chemical Journal*, IX., pp. 421–452, and X., pp. 1–20.

II. On the Digestibility of Fish.

Zeitschrift für Biologie, XXIV., p. 16.

III. On Food Consumption. (Dietaries of working people.)

Report of the Massachusetts Bureau of Statistics of Labor, 1886 pp. 238–326.

V. On the methods of chemical analysis used in the investigations.

American Chemical Journal, IX., pp. 311–324; X., pp. 111–119, 197–209, and 262–281.

The results have been set forth in more or less popular form, during the years 1880–1891, in the publications of the United States Fish Commission, the American Fisheries Association, the American Health Association, the Association of Bureaus of Labor, the Connecticut Board of Agriculture, the Oyster Commission of the State of New York, and in articles in the *Popular Science Monthly* and in the *Century Magazine*. Tabular summaries of the results of analyses have been printed in various text-books and hand-books, including König's *Chemie der Nahrungsmittel* and the *National Medical Dictionary*.

A considerable number of gentlemen have been associated with me in the investigations above referred to, as prosecuted in this laboratory. Mr. Chas. D. Woods has been actively connected with nearly all the work, and has had charge of much of it. Messrs. W. H. Jordan, G. P. Merrill, E. B. Vorhees, J. H. Long, Miles Beamer, H. B. Gibson, and G. Gehring, have taken part in the work of analysis. Messrs. E. W. Rockwood, H. B. Gibson, C. S. Videon, E. Welch, and J. S. Haynes, the last three as advanced students, have shared in the studies of dietaries. The last named gentlemen and Mr. E. M. Ball, also an advanced student, performed a number of the analyses in the investigations of methods. Mr. H. B. Gibson has conducted the larger portion of the experiments with the calorimeter.

I also take especial pleasure in mentioning the gifts generously contributed for sustaining the expenses of the investigations. These include $100 from Mr. A. R. Crittenden, of Middletown, for the analysis of fish; a like sum from Mr. E. G. Blackford, of the New York State Fish and Oyster Commissions, for those of oysters; and $1,000 from the firm of Thurber, Whyland & Co., of New York, through Mr. F. B. Thurber, in aid of the investigations of foods. From sums given by the late Hon. J. W. Alsop, of Middletown, in aid of investigations in this laboratory, and aggregating somewhat over $1,500, a portion, perhaps one-third, was used for the studies of food. And, finally, as means from other sources were from time to time inadequate, they were supplemented by myself.

THE COMPOSITION OF FOOD MATERIALS.

BY W. O. ATWATER AND CHAS. D. WOODS.

As stated in the preceding chapter, a very considerable number of analyses of food materials have been made in the laboratory during a number of years past. The specimens analyzed are:

1. *Food-fishes and Invertebrates.*—In the course of an investigation of the chemistry of American fishes, shell fish, and other marine and fresh-water invertebrates used for food, which was prosecuted under the auspices and with the aid of the United States Fish Commission, analyses were made of flesh and other organs of some one hundred and ninety specimens. Preliminary accounts of the results were given in the reports of the United States Fish Commission for 1880 and 1883; the principal chemical data were published in the *American Chemical Journal*, Vol. IX., p. 421, and Vol. X., p. 1, and full details are to appear in a monograph now in press and soon to be published by the United States Fish Commission. Figures for the composition and nutritive values of the materials which are in most frequent use are included in tables in other parts of this report.

2. *Food-materials analyzed in behalf of the Smithsonian Institution.*—In connection with the studies of the composition and nutritive values of fishes and invertebrates above referred to, examinations of other food materials, especially meats, seemed desirable. The more especial incentive to these analyses, however, was found in the needs of the Food Collection of the United States National Museum, in behalf of which not far from one hundred specimens of food materials were analyzed. The majority of these were meats, but a number of specimens of dairy products, eggs, and vegetable food materials were included.

3. *Food materials analyzed by the Experiment Station.* — In connection with the study of dietaries, which has been undertaken in coöperation with the United States Department of Labor, and some of the results of which are described by one of us in another chapter of this report, some thirty-six specimens of animal and vegetable foods were analyzed. The analyses of the rest, some eighteen specimens, mostly meats, were made by the Station independently.

The analyses of the food materials in the second and third categories above are here reported:

METHODS OF ANALYSIS.

The methods employed for preparing the materials for analysis, and for the analytical determinations, are described in outline in the Reports of the United States Fish Commission, and the volumes of the *American Chemical Journal*, and in detail in the monograph above referred to. A recapitulation will, therefore, suffice here.

ANIMAL FOODS.

Briefly stated, the methods used in the analyses of the meats, fish, eggs, and dairy products, are as follows:—

Separation of Flesh from Refuse (Sampling).—The sample, as received at the laboratory, was weighed, the flesh (edible portion) was then separated from the refuse (skin, bones, etc.), and both portions weighed. There was always a slight loss in the separation, evidently due to evaporation and to small fragments of the tissues that adhered to the hands and to the implements used in preparing the sample. The perfect separation of the flesh from the other tissues was difficult, but the loss resulting from this was small. In sampling the material for analysis, it was finely chopped, either in a tray or in a sausage cutter, and in each case was well mixed in a wooden tray.

Water and Water-Free Substance.—The drying was done in ordinary water ovens at a temperature of nominally 100, but actually about 96 to 98 degrees centigrade, as is usual in drying ovens. For each analysis of animal tissues (flesh), one or more samples of 50 to 100 grams of the freshly chopped substance were weighed on a watch glass or small plate, heated in a current of dry hydrogen for 24 to 48 hours, cooled, allowed to stand in the open air for about 24 hours, weighed, ground, sifted through a sieve with circular holes 1 mm. in diameter, bottled, and set aside for analysis. In case of very fat samples, which could not be worked through so fine a sieve, either a coarser sieve was used, or the substance was crushed as finely as practicable, and bottled without sifting. The preliminary drying of the specimens of eggs, cheese, and milk, was likewise conducted in hydrogen in the drying ovens.

For the complete drying, about two grams of the partly dried material were dried in hydrogen for three or four hours. It is extremely difficult to get an absolutely constant weight, though we find that this is in most cases approximately attained in three hours.

Nitrogen, Protein, Albuminoids, etc.—In the earlier work, the nitrogen was determined in the partly dried substance by the soda lime method; later, the method of Kjeldahl has been used. The protein is calculated by multiplying the percentages of nitrogen by 6.25. The nitrogenous matters in meats and fish, *i. e.*, in the materials which have practically no carbohydrates, are also estimated by substracting the sum of ether extract and ash from the water-free substance, or the sum of water, ether extract, and ash, from the fresh substance, the remainder being taken as "albuminoids, etc., by difference." While this is not an absolutely correct measure of the total nitrogenous matter, it is doubtless more nearly so than the product of the nitrogen by 6.25, and on this account it is used in the majority of cases in the final tables of composition of food materials. The methods for estimating the nitrogenous materials are discussed in the monograph on the chemistry of fish above mentioned.

Fat (Ether extract).—The fat was extracted with ether in the usual manner. The point at which the extraction is completed is not always easy to determine. For the most part, the extraction was continued for such time as experience indicated to be sufficient, and then the flask was replaced by another, and the extraction repeated until the new flask showed no increase in weight.

According to our experience, the fat of many animal tissues is much more difficult to extract than that of most vegetable substances. In general, the greater the percentage of fat in a substance, the more difficult is the removal of the last traces. The flesh of eels and the yolks of eggs we have found to be especially difficult of complete extraction; with the latter, this was the case, even when ether and alcohol were used alternately, and mixed together as solvents. Partly dried flesh is frequently so hard that the fineness of the material to be extracted seems to be a very important matter.

Ash.—Ash was determined by essentially the same method as that now recommended by the Association of Official Agricultural Chemists. The crude ash was practically free from coal. Carbon dioxide was not estimated in the ash.

VEGETABLE MATERIALS.

These were dried in hydrogen and the determinations of ether extract, nitrogen and ash, made as above described. The crude fibre was estimated by the so-called Weende method with such slight modifications of manipulation as have, in our experience, been found convenient. The process has been essentially as adopted by the Association of Official Agricultural Chemists.

The analyses were made in duplicate, except in cases where difficulties or discrepancies made the determinations uncertain, and they were repeated. It was not felt to be necessary to give the analytical details here. What their character would be may be inferred from those in the monograph on the chemistry of fish, above mentioned.

RESULTS OF ANALYSES.—DESCRIPTION OF TABLES

Analyses of Meats.—Tables 13 to 16 contain the results of the analyses of beef made in this laboratory.

In preparing specimens and descriptive labels for the Food Collection of the United States National Museum, analyses of meats seemed especially desirable. A beginning was made with beef. As Western beef is very largely used in the Eastern States, a specimen of "Chicago beef" was chosen for the purpose. From a carload which had been received at Middletown, a side was selected which was pronounced by the dealer to be prime, though not of the very first quality, and of medium fatness for such meat. The side was cut in such pieces as are usual in the New York market. The fore quarter was thus divided into fifteen and the hind quarter into nine "cuts." Each "cut" was weighed and a portion taken for analysis. The edible portion (flesh) and the refuse (bone, gristle, etc.,) were separated and each weighed by itself. In several instances the lean and fat of the flesh were separated and each analyzed by itself. The method used was that often employed in physiological laboratories for the purpose of getting the muscular tissue as free as possible from fat. The specimen was cut in fine pieces, and the fatty portions separated from the lean as accurately as could be done with knife, scissors, and pincers. The lean was thus mostly freed from particles of fat which were large enough to be visible to the naked eye, but, of course, considerable fat remained. One especial object was to learn the quantity of fat in this finely divided form in the muscular tissue. The several "cuts" of this side of beef are numbered from 155 to 179 in the tables. Nos. 285 to 294 were from another side, also of "Chicago beef," but judged by the dealer to be rather lean. Nos. 115 and 116 were purchased separately. They were pronounced to be of medium fatness. Nos. 283–4 were from a piece likewise bought in a Middletown market, but judged to be of rather more than medium fatness. The other specimens of beef were obtained at a boarding house where a dietary was being studied, and little was learned of these save that they were from the West.

In table 13, the analyses of 47 specimens of beef, calculated on water-free substance, are summarized. In the third column are figures for protein as found by multiplying the percentage of nitrogen by 6.25; in the last column are those for "albuminoids, etc.," by difference. It will be observed that in the majority of cases these two are not very far apart. In general, the leaner the meat the greater is the difference. The sums of the protein, fat, and ash, in the last column but one, bring out these differences more distinctly. In only two cases, where the fat is less than 40 per cent. of the water-free substance, does this sum fall below 100 per cent. In the muscular tissue from which all visible fat particles were removed before analysis, the footings of protein, fat, and ash, in several instances, are more than two per cent. above 100. This would seem to indicate, assuming the correctness of the determinations of fat and ash, that the nitrogen factor (6.25) was a little too large for the protein of muscular tissue of the animals whose flesh was here analyzed.

Table 14 gives the results of the same analyses as those in table 13, but calculated to the water content at time of analysis. The percentage composition of the fore quarter, hind quarter, and side, in this table and in table 15, were obtained by use of the data given in table 16.

It will be noticed that in general the percentages of water decrease as the percentages of fat increase, or, in other words, the higher the percentages of fat the higher are the percentages of water-free substance. That this should be the case where the quantities of fat are large is perfectly natural. Fatty tissue has extremely little water, while muscular tissue freed from visible fat is about three-fourths water. Hence, in the meat, or in an organ which is made up of both muscular (lean) and fatty tissue, the percentage of water will naturally be larger as the former and smaller as the latter preponderates. But this is not the whole of the matter. When the muscular tissue is freed from visible fat, there are great differences in the percentages of fat. A considerable number of observations upon the subject have accumulated in the course of our investigations. The inference to which they seem to point is that interstitial fat and water of muscular and other tissue to a certain extent replace each other. We have not made the histological studies necessary for a full explanation of the matter, nor do we as chemists assume to discuss it from the physiological standpoint; but the facts, as we have observed them, can easily be accounted for on the assumption that certain intercellular or intracellular space is occupied by fat if it is present, and by water if it is not. We have also had occasion to observe a similar relation between the nitrogenous material and water of muscular tissue. Thus we find the flesh (*i. e.*, muscular tissue) of fat salmon to contain not only much more fat, but also considerably more nitrogenous matter than that of spent salmon. It would seem that during the period in which the spawn is being elaborated, and, as it is claimed by competent authorities, the animal takes no food, both fat and albuminoids are consumed, and their place in the tissue is in part filled by water. The mutual replacement of water and fat occurs in other tissues as well as muscle. In bone, for instance, it is decidedly noteworthy.

Aside from the purely physiological and chemical interest of the question, it has economic and hygienic bearings of importance. The fact that so much fat in invisible particles can take the place of water in flesh, makes the differences in the composition and nutritive values of lean meat much greater than are commonly supposed. The excessive fatness of American meats is thus made worse than it appears to be,—a circumstance alike disadvantageous to the feeder, who produces more fat than he is paid for, and the consumer, who uses more than he needs or is well for his health. The subject is of sufficient scientific and practical interest to call for data and discussion which are hardly in place here, and we hope to revert to it on another occasion.

Table 15 contains the results of the analyses of the same specimens as the two preceding tables, but recalculated so as to include both edible portion and refuse, and thus represent the composition of the meat as actually sold at the market. The figures of tables 13 to 15 are for percentages. It will be interesting to note the absolute weights of the materials and their ingredients. Accordingly, in table 16 are given the weights of the several cuts as obtained at the market, the weights of refuse and edible portion in each, and also the weights of water, protein, fat, and ash, as calculated from the percentages in the preceding tables. In the case of the side of beef, which was made up of samples 155–179, the sums of the weights of the several cuts and of their constituents are the weights of the fore quarter, the hind quarter, and whole side and their constituents. These weights are given in table 16. From them the figures for percentage composition of the two quarters and the whole side in tables 14 and 15 were calculated.

A side of mutton and a side of lamb have been analyzed, as was done with the beef, and the results of the analyses are given in tables 17 to 20.

The analysis of the side of mutton was made in behalf of the National Museum. The specimen was from a Connecticut-grown sheep, two years old, and of medium fatness, and was divided in the usual manner into cuts, from which samples 128 to 136 were taken. The heart, lungs, and liver of the same animal were analyzed as 136, 137, and 138 of tables 27 and 28. The side of lamb from which 295–300 were taken was from a Connecticut-grown animal, six months old, and rather above medium fatness. Besides these cuts of the two sides, another sample (No. 117) was analyzed. It consisted of three ribs of what was described by the butcher of whom it was purchased as prime mutton from a yearling wether.

Table 17 gives results of the fifteen analyses of mutton and lamb, calculated on water-free substance of edible portion. The table is similar to that of table 13 for beef. In the next to the last column are given the sums of the protein, fat, and ash. It will be noted that in the majority of cases this sum is less than 100 per cent., and that in most cases in which it is over 100 per cent. the percentages of fat are very high. The extraction of the fat in the case of both the mutton and the lamb was very troublesome. The duplicate results were frequently very discordant, but in every case the results as given in the table are the averages of three or four different determinations. In the case of the mutton, the kidney and kidney fat were by an oversight analyzed together. It will be noted that with a very small percentage of nitrogen (1.2 %) and ash (0.5 %), the sum of the protein, fat, and ash is 2.25 per cent. above 100. That this was not due to any change in the fat during the partial drying, would seem probable from the fact that the percentages of fat in a sample dried in air averaged 94.18 per cent., or practically the same as that obtained from the material dried in hydrogen (94.20 %). In fact, the averages obtained from fat determined in the samples dried in the two different ways agreed more closely than the duplicate analyses in each sample. In 296 the footing is as high as that of the kidney fat, but in this case there is relatively a large percentage of nitrogen. As the determinations of both nitrogen and fat were repeated in the sample after an interval of some days, and the second results were practically identical with the first, it would seem probable that this is not due to errors in the analyses, but to some peculiarity of the sample itself.

Table 18 contains the analyses of the same samples as table 17, but calculated to the water content at time of purchase. The percentage composition of fore quarter, hind quarter, and whole side, in this table and in table 19, are obtained from the data given in table 20, in the manner explained in the description of the tables of analyses of the side of beef above.

Table 19 gives the results of the analyses of the same samples as the preceding tables calculated for the specimens as received, including both edible portion and refuse. The close agreement between the amounts of refuse and edible portion in the side of mutton and in that of lamb is doubtless largely accidental, and in case of other sides would probably not prove to be so close.

Table 20 gives the weight of the cuts and of their constituents, from which the weight of the two quarters and the whole side and their constituents were computed. It will be noticed that although the weights of the sides of mutton and lamb were nearly the same, and although the mutton was pronounced to be of medium, while the lamb was of more than medium fatness, yet, after deducting the kidney fat, there was a pound more of fat in the side of mutton than in the side of lamb. It is well understood that the meat of well-fattened mature animals has more fat than that of younger animals, but how wide is the difference is not generally appreciated.

Tables 21, 22, and 23 give the results of analyses of samples of veal, pork, chicken, and turkey. The reason for the large number of analyses of shoulder and chuck rib of pork is that these samples were taken in connection with the study of a dietary in a boarding-house in which these cuts were used.

It will be noticed (table 21) that in the case of veal and pork, the footings of the protein, fat, and ash do not vary greatly from 100 per cent., but that in the case of the flesh of chicken and turkey, these are about three per cent. above 100 in the water-free substance. If inference can be made from the turkey, in which the dark and white meat were analyzed separately, this difference belongs to the dark rather than to the white meat. The sum of the protein, fat, and ash in the water-free substance of the dark meat is 105.1 per cent., and in the white 100.4 per cent., implying that the dark meat contains nitrogenous compounds not as rich in nitrogen as the albuminoids generally.

In table 22 the results of the analyses of these samples are calculated to the water content at time of purchase.

Table 23 gives the composition of the total specimen as received, including both refuse and edible portion.

Tables 24, 25, and 26 contain the results of the analyses of fifteen specimens of cured and prepared meats, eight analyses of cheese, and one of butter. In table 24 the results are for water-free substance, and in table 25 they are calculated to water content at time of purchase. In table 26 the analyses of corned beef and ham are calculated on total specimen, flesh and refuse, as purchased. In the other specimens there was, strictly speaking, no refuse, although in the analysis the rind was removed from the salt pork and only the clear fat taken for analysis. In this case the rind was 2.8 per cent. of the whole. In one piece of dried beef as purchased there was a considerable adhering fat (tallow), which would not usually be eaten. This amounted to one-eighth of the whole, and was not included in sample analyzed.

Tables 27, 28, and 29 contain the results of the analyses of some of the organs of different animals. In table 27 the analyses are calculated on water-free substance. That the sum of the percentages of protein, fat, and ash, of the liver and kidney, should be less than 100, was to be expected, since these organs contain varying amounts of non-nitrogenous materials other than fat. On this account an extra column is introduced into the table, giving the nitrogen-free extract as found by difference, *i. e.*, by subtracting the sum of the protein, fat, and ash from 100. It will be noticed that the sums of the percentages of the protein, fat, and ash in most of the specimens are reasonably near 100, although, with the exception of the chicken gizzard, they all fall a little below that figure. In the case of tripe, the difference is so great that the percentage of albuminoids by difference is not computed. There are also given in this table the results of the analyses of two samples of hens' eggs. The yolks and whites were analyzed separately. It will be observed that while the protein, fat, and ash of the yolks make about 100 per cent., the sum of these ingredients of the whites of eggs falls much below 100. Since the white of an egg is presumably very nearly pure albumen, the albuminoids are estimated by difference.

Table 28 contains the results of the analyses of the materials of table 27 recalculated to the water content at time of purchase, and table 29 gives the results of the analyses of the eggs as calculated to whole specimen, refuse (shells), and shell contents.

Tables 30 and 31 contain the results of the analyses of vegetable foods which have been made here, and have not been previously published. Table 30 gives the composition of the water-free substance, and table 31 that of the substance as received for analysis.

NOTES ON SAMPLES ANALYZED.

Beef (Tables 1–4).—Samples 153 to 179, inclusive, were from the same side of beef. It was butchered in Chicago, and purchased at a market in this city. The side was called an average one as regards weight, fatness, etc. Its total weight at the car was 326 pounds, the fore quarter weighing 176 pounds and the hind quarter 150 pounds. It will be noticed in table 16 that the footings of the weights of the individual cuts make the side weigh 317.6 pounds, and that the falling off in weight was almost wholly in the hind quarter, which weighed 150 pounds at the car, and by individual cuts only 142 pounds. The side, when received, was partly frozen, and the fore quarter was analyzed first. These two facts may account for the shrinkage of the hind quarter. The cuts were made in accordance with the usage in New York markets. The weights of the cuts are given in table 16.

115. *Porter-house Steak.*—The sample taken was from medium fat Chicago beef. The piece taken for analysis was the second cut from the tenderloin, and weighed at the shop 1.25 pounds.

116. *Round Steak.*—The sample taken was from medium fat Chicago beef, and from the tender part ("top side") of round, at about the middle of the leg. The sample weighed a little over one pound.

283–4. *Sirloin.*—A medium sirloin steak, taken from the middle of the sirloin. The whole side weighed about 300 pounds, and was of medium fatness, being above, rather than below, the average. The lean was analyzed as 283, and the fat as 284.

285. *Round Steak.*—This was a fair sample of the round, from a side of rather lean Chicago beef. The whole side weighed about 300 pounds. The weight of the sample at the market was four pounds. Only the lean, from which all visible fat and connective tissue were removed, was used in the analysis.

286–7. *Rump.*—From the same side as 285. Its weight at market before trimming was 6.5 pounds; after trimming, 5.5 pounds. The trimmings were all fat, and were included in the sample for analysis. The "clear" lean was analyzed as 286, and the "clear" fat as 287.

288. *Shoulder Steak.*—From the same side as 285–287. Its weight at market before trimming was 2.75 pounds; after trimming, 2.5 pounds. The trimmings were all bone, and were included in the sample. The fat was neglected, and only "clear" lean used, in the analysis.

289–90. *Second-cut Chuck Rib.*—This was from the same side as 285-8. Its weight at market before trimming was 5.5 pounds; after trimming, 4.75 pounds. The trimmings were mostly bone, and were included in the sample. The "clear" lean was analyzed as 289, and the "clear" fat as 290.

291-2. *Shoulder Clod.*—From same side as 285 to 290. Weight at the shop before trimming, 5.5 pounds; after trimming, 5 pounds. The trimmings were all bone, and were included in sample. The "clear" lean was analyzed as 291, the "clear" fat as 292.

293-4. *Hip Sirloin.*—From same side as samples 285 to 292. Weight at shop before trimming, 4 pounds; after trimming, 3.5 pounds. The trimmings were partly fat and partly bone, and were included in sample. The "clear" lean was analyzed as 293, and the "clear" fat as 294.

Samples 306, 308, 315, 316, 320, 325, 329, and 332 were taken in connection with the study of the dietary of a boarding-house in Middletown, and in consequence of this, comparatively little is known as to the quality of the sides of beef from which they were taken, other than that it was all western butchered. The samples were taken untrimmed, and as in the case of the other samples analyzed, the refuse would contain a larger percentage of bone than would be found in trimmed beef. It is to be remembered, however, that it is customary in our markets to weigh the cuts of beef before they are trimmed.

Mutton and Lamb (Tables 17, 18, 19, 20).—Samples 128 to 135 were from a Connecticut-grown sheep, two years old, of about medium fatness. One whole side was taken for analysis, the different cuts being made in the usual manner, as specified in the tables. Through an oversight, the kidney and kidney fat were analyzed together. The heart, the lungs, and the liver from this sheep were analyzed as 135, 136, 137, and 138, and the results of the analyses are given in tables 27 and 28.

Sample 117 consisted of three ribs from the fore quarter, described by the butcher as prime mutton from a yearling wether. The animal was probably from the State of New York. The fat and lean were analyzed separately. The fat was freed from the lean as completely as practicable, thus leaving considerable fat with the lean, but no lean with the fat.

Samples 295, 296, 298, 299, and 300 were taken from the side of a native-grown lamb, six months of age. The dressed weight of the lamb was about 39 pounds. It was above, rather than under, medium fatness. Sample 295 was the loin, but it included neither the kidney nor kidney fat. The cuts were taken in the usual way.

Veal (Tables 21, 22, and 23).—Only two samples of veal have been analyzed, and these were taken in connection with the study of a dietary. Sample 314 was from the shoulder, and 319 was taken from a miscellaneous lot of veal to be used in a pot pie, and consisted of different parts, though principally flank and shoulder.

Fresh Pork (Tables 21, 22, and 23).—The samples of fresh pork were also taken in connection with the study of a dietary. The cuts used were for roasts, and included part of the shoulder and part of the chuck rib. In 326 and 333 only a small part of the chuck rib was included, and the cuts are consequently called "shoulder." In 302 and 309 a considerable part of the chuck rib was included, and the samples are described as shoulder and chuck rib.

Chicken and Turkey.—Tables 21, 22, and 23.

142. *Chicken.*—Common yard fowl, about eight months old, and of average fatness.

149. *Turkey*—A hen turkey, probably raised in Massachusetts. It was described as "fair young turkey." The analysis was made in January, and the turkey was hatched in the preceding spring. The white and dark meats were analyzed separately.

Preserved Meats and Cheese.—Tables 24, 25, and 26.

185. *Corned Beef.*—This sample was from the same cut as the specimen of fresh beef analyzed as 174.

322 and 330. *Corned Beef, Flank.*—Sample 322 was of more than average fatness, and not very thoroughly corned.

86. *Canned Corned Beef.*—Sample consisted of one can of corned beef, labeled as packed by Libby, McNeil & Libby, of Chicago. The total can contents weighed 729 grams.

331. *Canned Corned Beef.*—Sample consisted of two cans, labeled as packed by same firm as 86. The weights of the can contents were 738 and 777 grams.

197. *Salted and Dried Beef.*—The sample consisted of 1.6 pounds, from the inside of leg. It had been pickled in Chicago, shipped to Middletown in brine, and then dried and lightly smoked. About one-eighth of this sample (12.54 per cent.) was clear fat. The dealer said that the most of this fat was removed before selling, and it was not included in the portion analyzed.

231. *Salted and Dried Beef.*—Sample consisted of section from the inside of leg. Sample as purchased contained but little clear fat, and the whole was analyzed.

198. *Salt Pork.*—The sample consisted of 1.5 pounds of "backs," western grown and eastern packed. It contained a "streak" of lean (17.4 per cent.). The rind made up 2.8 per cent. of the sample. Only the "clear" fat was used in the analysis.

140. *Smoked Ham.*—Sample consisted of one whole ham, western grown and eastern cured. It was said to be an average sugar-cured ham. The total weight was 14.4 pounds. 87.6 per cent. of the ham was edible, of which 54.8 per cent. was "clear" lean, and 32.9 per cent. "clear" fat.

301. *Bologna Sausage.*—Purchased in Middletown. The case made up 1.1 per cent. of the whole, and was not included in the sample as analyzed.

141. *Pork Sausage.*—Sample consisted of four links of ordinary sausage, prepared by Sperry & Barnes, of New Haven. The case was 2.4 per cent. of the whole, and was not included in the analysis.

311. *Pork Sausage.*—Sample consisted of two pounds of pork sausage, purchased in Middletown. Case included in analysis. From the lowness of the footing of the protein, fat, and ash (95.29 per cent.), it would seem probable that considerable amounts of sugar, etc., were used in its preparation.

187. *Cheese.*—Very rich New York factory cheese.

252. *Cheese.*—A full cream factory cheese.

268. *Cheese.*—A full cream cheese, made at factory No. 10, Sandusky, N. Y.

264. *Cheese.*—A full cream "English Dairy" cheese, made at Otsego, N. Y.

265. *Cheese.*—A skimmed-milk cheese, made in Pennsylvania.

266. *Cheese.*—Sample consisted of two "Neufchatel" cheeses, of American manufacture. The average weight was 78 grams, of which tin-foil and paper made up 7.1 per cent.

267. *Cheese.*—Swiss cheese, "Schweitzer kase." Said to have been imported.

Animal Organs and Hens' Eggs.—Tables 27, 28, and 29.

152. *Beef Liver.*—Western butchered. Sample frozen when purchased.

178. *Beef Kidney.*—From same side of beef as 153–176.

184 *(Beef Heart)* and 183 *(Beef Tongue)* were from western butchered beef.

136 *(Sheep Heart)*, 137 *(Sheep Lungs)*, and 138 *(Sheep Liver)*, were from the same sheep as samples 128–135.

177. *Beef Marrow.*—From leg bone.
143. *Chicken Liver.*—Sample consisted of six livers.
144. *Chicken Heart.*—Sample consisted of six hearts.
145. *Chicken Gizzard.*—Sample consisted of three gizzards.
146. *Turkey Heart.*—Sample consisted of three hearts.
148. *Turkey Gizzard.*—One gizzard from the turkey analyzed as 149.

150. *Hens' Eggs.*—Sample consisted of 12 eggs, laid by grain-fed Plymouth Rock hens. Eggs boiled before being analyzed. Weight before boiling, 742 grams; weight after, 731 grams. The shells made up 10.7 per cent. of the whole.

196. *Hens' Eggs.*—Sample consisted of six eggs, laid by grain-fed Buff Cochin hens. Cooked before analyzing. Weight before boiling, 402 grams, and after, 391 grams. The shells were 10.9 per cent. of the whole sample.

Vegetable Foods.—Tables 30 and 31.

189, 190, 222, and 223. *Wheat Bread.*—Samples were purchased at different times from two bakeries in Middletown. Nos. 189 and 223 were said to have been made from patent process, and 190 and 222 from a mixture of St. Louis (white wheat) and Indianapolis (spring wheat) flour.

213. *Wheat Bread.*—This sample was made at a private house, from flour analyzed as 210 and butter analyzed as 216. The materials used in making the bread were:—2760 grams of flour, 27.2 grams of butter, 5.45 grams of salt, and 16.7 grams of yeast.

193 *(Graham Bread)* and 188 *(Rye Bread)* were purchased in Middletown.

191, 192, 194, 195, 199, and 200. *Crackers.*—Purchased in Middletown.

214 and 226 *(Oat Meal)*, and 215 and 227 *(Cracked Wheat)*.—Purchased in Middletown.

303 *(Canned Corn)*, 304 *(Canned Peas)*, and 305 *(Canned Tomatoes)* were purchased in Middletown. Aside from weights of can contents and brands upon the cans, nothing is known of the specimens other than is given in the tables.

323. *Cabbage.*—Sample consisted of a head of winter cabbage. The outer leaves (15.5 per cent.) of the cabbage were removed, and only the inner edible leaves were included in the analysis.

327. *Cranberries.*—The whole berries taken for analysis.

335. *Catawba Grapes.*—Grown in New York. The stems and skins, 24.7 per cent., were not included in the sample as analyzed.

For explanation of tables see page 49, and for description of samples see page 55. For average composition of American foods see tables 32 and 33, beyond.

TABLE 13.

Composition of Water-free Substance of Edible Portion of Beef.

PORTION TAKEN FOR ANALYSIS.	Laboratory No.	Nitrogen.	Protein (N. × 6.25).	Fat.	Ash.	Protein, Fat, and Ash.	Albuminoids, etc., (by Difference).
Side, Medium Fat.		%	%	%	%	%	%
First cut neck, - -	161	7.64	47.75	51.19	2.42	101.36	46.39
Second cut neck, - -	160	9.09	56.83	40.80	3.02	100.65	56.18
Third cut neck, - -	159	8.19	51.19	45.49	2.69	99.37	51.82
First cut chuck ribs, -	165	5.99	37.44	61.34	2.09	100.87	36.57
Second cut chuck ribs, -	162	7.46	46.63	48.48	2.79	97.90	48.73
Third cut chuck ribs, -	163	8.37	52.31	45.90	3.02	101.23	51.08
First cut ribs, - . -	167	4.58	28.63	69.00	1.64	99.27	29.36
Second cut ribs, - -	166	4.63	28.94	69.85	1.67	100.46	28.48
Third cut ribs, - -	164	4.82	30.13	68.86	1.70	100.69	29.44
Brisket, - - - -	158	4.16	26.00	70.69	1.54	98.23	27.77
Shoulder-clod, - - -	154	9.94	62.13	34.55	3.56	100.24	61.89
Cross-ribs, - - -	157	3.94	24.63	74.13	1.36	100.12	24.51
Shin, - - - - -	153	13.99	87.46	8.78	4.76	101.00	86.46
Plate, - - - - -	156	4.35	27.19	70.85	1.44	99.48	27.71
Navel, - - - - -	155	4.75	29.69	69.52	1.58	100.79	28.90
Small end sirloin, - -	176	6.72	42.00	54.80	2.22	99.02	42.98
Hip sirloin, - - -	175	6.68	41.76	55.76	2.29	99.81	41.95
Socket, - - - -	172	6.29	39.32	58.76	2.37	100.45	38.87
Rump, - - - -	174	4.02	25.13	74.18	1.31	100.62	24.51
First cut round, - -	168	9.20	57.50	39.48	3.17	100.15	57.35
Second cut round, - -	169	10.87	67.94	28.16	4.36	100.46	67.48
Leg, - - - - -	171	11.99	74.94	20.33	4.31	99.58	75.36
Top of sirloin, - - -	173	3.80	23.75	75.57	1.31	100.63	23.12
Flank, - - - - -	170	2.75	17.19	82.55	.90	100.64	16.55
Kidney fat, - - -	179	0.17	1.06	98.88	.20	100.14	.92
Miscellaneous Cuts.							
Porter-house steak, - -	115	9.02	56.37	40.68	3.58	100.63	55.74
Sirloin, lean, - - -	283	13.31	83.19	13.63	4.41	101.23	81.96
Sirloin, fat, - - -	284	1.11	6.94	92.98	.51	100.43	6.51
Sirloin, lean plus fat, -	—	7.19	45.02	53.36	2.44	100.82	44.20
Rump, lean, - - -	286	12.98	81.13	14.37	4.23	99.73	81.40
Rump, fat, - - -	287	.14	.89	98.83	.17	99.89	1.00
Rump, lean plus fat, -	—	5.83	36.55	61.28	1.97	99.80	36.75
Round steak, - - -	116	11.30	70.63	26.88	3.36	100.87	69.76
Round, lean, - - -	285	14.15	88.44	9.30	4.73	102.47	85.97
Shoulder steak, - -	119	9.02	56.38	41.63	2.43	100.44	55.94
Shoulder clod, lean, -	291	14.02	87.63	8.28	4.59	100.50	87.13

TABLE 13.—*(Continued.)*

PORTION TAKEN FOR ANALYSIS.	Laboratory No.	Nitrogen.	Protein (N. × 6.25).	Fat.	Ash.	Protein, Fat, and Ash.	Albuminoids, etc., (by Difference).
Miscellaneous Cuts.		%	%	%	%	%	%
Shoulder clod, fat, - -	292	.30	1.85	97.87	.18	99.90	1.95
Shoulder clod, lean plus fat,	—	8.40	52.65	44.69	2.80	100.14	52.51
Shoulder, lean, - -	288	13.64	85.25	10.76	4.81	100.82	84.43
Shoulder, - - -	308	7.73	48.31	52.50	2.35	103.16	45.15
Shoulder, - - -	316	8.02	50.13	49.40	2.60	102.13	48.00
Shoulder, - - -	320	10.36	64.75	32.57	3.17	100.49	64.26
Shoulder, average, - -	—	8.70	54.40	44.82	2.71	101.93	52.47
Chuck ribs, - - -	306	5.58	34.88	64.23	1.75	100.86	34.02
Chuck ribs, - - -	318	5.43	33.94	65.61	1.50	101.05	32.89
Chuck ribs, - - -	325	8.62	53.88	43.61	2.95	100.44	53.44
Chuck ribs, - - -	329	7.49	46.81	51.95	2.45	101.21	45.60
Chuck ribs, average,	—	6.78	42.38	56.35	2.16	100.89	41.49
Second cut chuck rib, lean,	289	13.93	87.06	10.96	4.36	102.38	84.68
Second cut chuck rib, fat,	290	.45	2.84	96.91	.30	100.05	2.79
Second cut chuck rib, lean,	—	6.41	40.13	58.83	2.09	101.05	39.08
Third cut ribs, - -	315	5.34	33.38	65.56	2.23	101.17	32.21
Rib cut free from bone, -	332	4.63	28.94	69.64	1.44	100.02	28.92

TABLE 14.

Composition of Flesh (Edible Portion) of Beef.

PORTION TAKEN FOR ANALYSIS.	Laboratory No.	Water.	Water-free Substance.	Albuminoids, etc., (by Difference).	Fat.	Ash.	Protein (N. × 6.25).	Water, Protein, Fat, and Ash.
Side, Medium Fat.		%	%	%	%	%	%	%
First cut neck, -	161	60.64	39.36	18.26	20.15	.95	18.79	100.53
Second cut neck, -	160	64.48	35.52	19.96	14.49	1.07	20.18	100.22
Third cut neck, -	159	61.00	39.00	20.21	17.74	1.05	19.96	99.75
Total neck, - -	—	61.99	38.01	19.25	17.74	1.02	—	—
First cut chuck ribs,	165	53.11	46.89	17.15	28.76	.98	17.56	100.41
Second cut chuck ribs,	162	58.21	41.79	20.38	20.25	1.16	19.50	99.12
Third cut chuck ribs,	163	63.67	36.33	18.57	16.67	1.09	18.95	100.38
Total chuck ribs, -	—	58.06	41.94	19.06	21.78	1.10	—	—
First cut ribs, -	167	46.21	53.79	15.82	37.09	.88	15.38	99.56
Second cut ribs, -	166	48.64	51.36	14.63	35.87	.86	14.86	100.23
Third cut ribs, -	164	48.48	51.52	15.16	35.48	.88	15.52	100.36
Total ribs, - -	—	47.82	52.18	15.22	36.08	.88	—	—

TABLE 14.—*(Continued.)*

PORTION TAKEN FOR ANALYSIS.	Laboratory No.	Water.	Water-free Substance.	Albuminoids, etc., (by Difference).	Fat.	Ash.	Protein (N. × 6.25).	Water, Protein, Fat, and Ash.
Side, Medium Fat.		%	%	%	%	%	%	%
Brisket, - -	158	47.41	52.59	14.58	37.20	.81	13.68	99.10
Shoulder clod, -	154	66.61	33.39	20.66	11.54	1.19	20.74	100.08
Cross ribs, - -	157	43.95	56.05	13.73	41.56	.76	13.80	100.07
Shin, - - -	153	73.80	26.20	22.66	2.30	1.24	22.90	100.24
Plate, - - -	156	44.36	55.64	15.41	39.43	.80	15.13	99.72
Navel, - - -	155	47.59	52.41	15.14	36.44	.83	15.56	100.42
Total fore quarter,	—	54.12	45.88	17.27	27.65	.96	—	—
Small end sirloin, -	176	60.68	39.32	16.92	21.53	.87	16.50	99.58
Hip sirloin, - -	175	58.86	41.14	17.26	22.94	.94	17.18	99.92
Small end and hip sirloin, - -	—	59.86	40.14	17.07	22.17	.90	—	—
Socket, - - -	172	57.12	42.88	16.67	25.19	1.02	16.86	100.19
Rump, - - -	174	40.23	59.77	14.65	44.34	.78	15.02	100.37
First cut round, -	168	66.04	33.96	19.48	13.40	1.08	19.53	100.05
Second cut round,	169	69.53	30.47	20.57	8.57	1.33	20.71	100.14
First cut and second cut round, - -	—	66.76	33.24	19.71	12.40	1.13	—	—
Leg, - - -	171	72.15	27.85	20.99	5.66	1.20	20.87	99.88
Top of sirloin, -	173	42.20	57.80	13.36	43.68	.76	13.75	100.39
Flank, - - -	170	27.45	72.55	12.01	59.89	.65	12.47	100.46
Total hind quarter, except kidney fat,	—	55.66	44.34	17.11	26.27	.96	—	—
Kidney fat, - -	179	4.30	95.70	.89	94.62	.19	1.02	100.13
Whole side, - -	—	52.43	47.57	16.44	30.20	.93	—	—
Whole side, except kidney fat, -	—	54.77	45.23	17.20	27.07	.96	—	—
Miscellaneous Cuts.								
Porter-house steak,	115	60.50	39.50	22.01	16.08	1.41	22.26	100.25
Sirloin, - - -	283–4	59.82	40.18	17.76	21.44	.98	18.09	100.33
Rump, - - -	286–7	56.28	43.72	16.07	26.79	.86	15.98	99.91
Round steak, -	116	69.12	30.88	21.54	8.30	1.04	21.81	100.27
Shoulder steak, -	119	65.33	34.67	19.40	14.43	.84	19.55	100.15
Shoulder clod, -	291–2	63.97	36.03	18.90	16.12	1.01	18.99	100.09
Shoulder, - -	308	62.09	37.91	17.12	19.90	.89	18.31	101.19
Shoulder, - -	316	56.23	43.77	21.01	21.62	1.14	21.94	100.93
Shoulder, - -	320	69.18	30.82	19.80	10.04	.98	19.96	100.16
Shoulder, average,	—	62.50	37.50	19.31	17.19	1.00	20.07	100.76
Chuck ribs, - -	306	52.82	47.18	16.05	30.30	.83	16.46	100.41
Chuck ribs, - -	318	51.29	48.71	16.02	31.96	.73	16.53	100.51
Chuck ribs, - -	325	66.19	33.81	18.06	14.75	1.00	18.22	100.16
Chuck ribs, - -	329	61.38	38.62	17.61	20.06	.95	18.08	100.47
Chuck ribs, average,	—	57.92	42.08	16.93	24.27	.88	17.32	100.39
Second cut chuck rib,	289–90	56.93	43.07	16.84	25.33	.90	17.28	100.44
Third cut ribs, -	315	49.88	50.12	16.14	32.86	1.12	16.73	100.59
Rib free from bone,	332	47.44	52.56	15.20	36.60	.76	15.21	100.01

TABLE 15.

Composition of Side of Beef as received, including both Edible Portion and Refuse.

PORTION TAKEN FOR ANALYSIS.	Laboratory Number.	Refuse.	Edible Portion (Including Loss).	EDIBLE PORTION.				
				Water.	Water-free Substance.	Nutrients.		
						Albuminoids, etc. (by difference).	Fat.	Ash.
Side, Medium Fat.		%	%	%	%	%	%	%
First cut neck,	161	18.37	81.63	49.50	32.13	14.90	16.45	.78
Second cut neck,	160	18.74	81.26	52.40	28.86	16.22	11.77	.87
Third cut neck,	159	22.86	77.14	47.06	30.08	15.59	13.68	.81
Total neck,	——	19.54	80.46	49.88	30.58	15.49	14.27	.82
First cut chuck ribs,	165	19.45	80.55	42.78	37.77	13.82	23.16	.79
Second cut chuck ribs,	162	19.59	80.41	46.81	33.60	16.39	16.28	.93
Third cut chuck ribs,	163	16.31	83.69	53.29	30.40	15.54	13.95	.91
Total chuck ribs,	——	18.80	81.20	47.14	34.06	15.48	17.69	.89
First cut ribs,	167	21.36	78.64	36.34	42.30	12.44	29.17	.69
Second cut ribs,	166	22.70	77.30	37.60	39.70	11.31	27.73	.66
Third cut ribs,	164	20.35	79.65	38.61	41.04	12.07	28.26	.71
Total ribs,	——	21.34	78.66	37.62	41.04	11.97	28.38	.69
Brisket,	158	14.33	85.67	40.62	45.05	12.49	31.87	.69
Shoulder clod,	154	15.62	84.38	56.21	28.17	17.43	9.74	1.00
Cross ribs,	157	12.17	87.83	38.60	49.23	12.06	36.50	.67
Shin,	153	40.16	59.84	44.16	15.68	13.56	1.38	.74
Plate,	156	17.90	82.10	36.42	45.68	12.65	32.37	.66
Navel,	155	11.41	88.59	42.16	46.43	13.41	32.28	.74
Total fore quarter,	——	18.45	81.55	44.13	37.42	14.09	22.55	.78
Small end sirloin,	176	24.46	75.54	45.84	29.70	12.78	16.26	.66
Hip sirloin,	175	27.32	72.68	42.78	29.90	12.54	16.68	.68
Small end and hip sirloin,	——	25.79	74.21	44.42	29.79	12.67	16.45	.67
Socket,	172	35.79	64.21	36.68	27.53	10.70	16.17	.66
Rump,	174	16.18	83.82	33.72	50.10	12.28	37.17	.65
First cut round,	168	7.74	92.26	60.93	31.33	17.97	12.36	1.00
Second cut round,	169	32.12	67.88	47.20	20.68	13.96	5.82	.90
First cut and second cut round,	——	14.13	85.87	57.33	28.54	16.92	10.65	.97
Leg,	171	62.22	37.78	27.26	10.52	7.93	2.14	.45
Top of sirloin,	173	3.23	96.77	40.84	55.93	12.93	42.27	.73
Flank,	170	11.47	88.53	24.30	64.23	10.63	53.02	.58
Total hind quarter except kidney fat	——	20.23	79.77	44.40	35.37	13.65	20.96	.76
Kidney fat,	179	0.00	100.00	4.30	95.70	0.89	94.62	.19
Whole side,	——	18.48	81.52	42.74	38.78	13.40	24.62	.76
Whole side, except kidney fat,	——	19.21	80.79	44.25	36.54	13.90	21.87	.77
Miscellaneous cuts.								
Porter-house steak,	115	13.05	86.95	52.60	34.35	19.14	13.98	1.23
Sirloin,	283,4	12.98	87.02	52.05	34.97	15.46	18.66	.85
Rump,	286,7	6.55	93.45	52.59	40.86	15.02	25.04	.80
der steak,	119	12.25	87.75	57.33	30.42	17.02	12.66	.74
Shoulder clod,	291,2	10.67	89.33	57.15	32.18	16.88	14.40	.90
Shoulder,	308	13.30	86.70	53.83	32.87	14.84	17.26	.77
Shoulder,	316	11.30	88.70	49.88	38.82	18.64	19.17	1.01
Shoulder,	320	12.40	87.60	60.60	27.00	17.34	8.80	.86
Shoulder average,	——	12.33	87.67	54.77	32.90	16.94	15.08	.88
Chuck ribs,	306	5.40	94.60	49.97	44.63	15.18	28.67	.78
Chuck ribs,	318	15.00	85.00	43.60	41.40	13.62	27.16	.62
Chuck ribs,	325	9.80	90.20	59.70	30.50	16.29	13.31	.90
Chuck ribs,	329	11.40	88.60	54.38	34.22	15.60	17.78	.84
Chuck ribs average,	——	10.40	89.60	51.91	37.69	15.17	21.73	.79
Second cut chuck ribs,	289,90	19.65	80.35	45.74	34.61	13.53	20.36	.72
Third cut ribs,	315	19.40	80.60	40.20	40.40	13.01	26.49	.90

TABLE 16.

Composition of Side of Beef of Medium Fatness. Refuse (Edible Portion) and Nutrients expressed in Pounds.

PORTION TAKEN FOR ANALYSIS.	Laboratory Number.	In Whole Specimen, as taken for Analysis.						
		Total Weight of Cut.	Refuse,	Edible Portion.	Edible Portion.			
					Water.	Albuminoids, (by difference.)	Fat.	Ash.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
First cut neck, -	161	8.09	1.48	6.61	4.01	1.21	1.33	.06
Second cut neck,	160	6.05	1.13	4.92	3.18	.98	.71	.05
Third cut neck, -	159	4.33	.99	3.34	2.04	.67	.59	.04
Total neck, -	—	18.47	3.60	14.87	9.23	2.86	2.63	.15
First cut chuck ribs,	165	11.75	2.28	9.47	5.03	1.63	2.72	.09
Second cut chuck ribs, - -	162	20.60	4.04	16.56	9.64	3.38	3.35	.19
Third cut chuck ribs,	163	9.44	1.54	7.90	5.03	1.47	1.32	.08
Total chuck ribs,	—	41.79	7.86	33.93	19.70	6.48	7.39	.36
First cut ribs, -	167	7.23	1.54	5.69	2.63	.90	2.11	.05
Second cut ribs, -	166	6.82	1.55	5.27	2.56	.77	1.89	.05
Third cut ribs, -	164	9.41	1.91	7.50	3.63	1.14	2.66	.07
Total ribs, -	—	23.46	5.00	18.46	8.82	2.81	6.66	.17
Brisket, - -	158	13.64	1.96	11.68	5.54	1.70	4.35	.09
Shoulder clod, -	154	17.15	2.68	14.47	9.64	2.99	1.67	.17
Cross ribs, - -	157	14.76	1.80	12.96	5.69	1.78	5.39	.10
Shin, - - -	153	11.11	4.46	6.65	4.91	1.51	.15	.08
Plate, - - -	156	15.37	2.75	12.62	5.60	1.94	4.98	.10
Navel, - -	155	19.51	2.23	17.28	8.22	2.62	6.30	.14
Total fore quarter,	—	175.26	32.34	142.92	77.35	24.69	39.52	1.36
Small end sirloin,	176	13.44	3.29	10.15	6.16	1.72	2.18	.09
Hip sirloin, -	175	11.74	3.21	8.53	5.02	1.47	1.96	.08
Small end and hip sirloin, - -	—	25.18	6.50	18.68	11.18	3.19	4.14	.17
Socket, - -	172	9.66	3.46	6.20	3.55	1.03	1.56	.06
Rump, - -	174	12.61	2.04	10.57	4.25	1.55	4.69	.08
First cut round, -	168	37.52	2.90	34.62	22.87	6.74	4.64	.37
Second cut round,	169	13.33	4.28	9.05	6.29	1.86	.78	.12
First cut and second cut round, -	—	50.85	7.18	43.67	29.16	8.60	5.42	.49
Leg, - - -	171	8.58	5.34	3.24	2.34	.68	.18	.04
Top of sirloin, -	173	10.24	.33	9.91	4.18	1.33	4.33	.07
Flank, - -	170	13.18	1.51	11.67	3.21	1.40	6.99	.07
Total hind quarter, except kidney fat,	—	130.30	26.36	103.94	57.87	17.78	27.31	.98
Kidney fat, - -	179	12.00	——	12.00	.52	.11	11.35	.02
Whole side, - -	—	317.56	58.70	258.86	135.74	42.58	78.18	2.36
Whole side, except kidney fat, -	—	305.56	58.70	246.86	135.22	42.47	66.83	2.34

TABLE 17.

Composition of Water-free Substance of Edible Portion of Mutton and Lamb.

Portion Taken for Analysis.	Laboratory Number.	Nitrogen.	Protein (N. × 6.25).	Fat.	Ash.	Protein, Fat, and Ash.	Albuminoids, etc., (by difference)
Side of Mutton.		%	%	%	%	%	%
Shoulder, - - - - -	128	6.97	43.56	54.09	2.28	99.93	43.63
Breast, - - -	129	3.51	21.94	75.60	1.62	99.16	22.78
Neck, - - - - -	130	5.75	35.94	61.76	1.79	99.49	36.45
Rack, - - - - -	131	6.47	40.44	57.50	1.72	99.66	40.78
Leg, - - - - - -	132	7.59	47.43	49.69	2.36	99.48	47.95
Loin, - - - - -	133	4.69	29.31	69.01	1.43	99.75	29.56
Flank, - - - - -	134	4.07	25.44	73.48	.75	99.67	25.77
Kidney and kidney fat, -	135	1.21	7.56	94.20	.50	102.26	5.30
Mutton, Miscellaneous Cuts.							
Mutton chop, lean, - -	117*a*	8.74	54.63	42.45	2.53	99.61	55.02
Mutton chop, fat, - -	117*b*	.95	5.94	94.44	.30	100.68	5.26
Mutton chop, lean plus fat,	—	5.67	35.47	62.88	1.65	100.00	35.47
Side of Lamb.							
Shoulder, - - - -	298	6.00	37.50	61.54	2.12	101.16	36.34
Breast, - - - - -	299	6.96	43.50	53.91	2.31	99.72	43.78
Neck, - - - - -	300	6.53	40.81	57.28	2.27	100.36	40.45
Leg, - - - - - -	296	8.95	55.94	43.38	3.04	102.36	53.58
Loin, - - - - -	295	6.89	43.06	55.60	2.34	101.00	42.06

TABLE 18.

Composition of Flesh (Edible Portion) of Mutton and Lamb.

Portion Taken for Analysis.	Laboratory Number.	Water.	Water-free Substance.	Albuminoids, etc. (by difference)	Fat.	Ash.	Protein (N. × 6.25).	Water, Protein, Fat, and Ash.
Side of Mutton.		%	%	%	%	%	%	%
Shoulder, - -	128	58.56	41.44	18.08	22.41	.95	18.05	99.97
Breast, - - -	129	37.60	62.40	14.22	47.17	1.01	13.69	99.47
Neck, - - -	130	55.69	44.31	16.16	27.36	.79	15.93	99.77
Rack, - -	131	54.94	45.06	18.38	25.91	.77	18.22	99.84
Fore quarter, - -	—	52.22	47.78	16.96	29.88	.94	——	——
Leg, - - -	132	61.80	38.20	18.32	18.98	.90	18.12	99.80
Loin, - - -	133	49.27	50.73	14.99	35.01	.73	14.87	99.88
Flank, - - -	134	38.73	61.27	15.78	45.03	.46	15.59	99.81
Hind quarter, -	—	54.67	45.33	16.92	27.53	.88	——	——
Kidney and kidney fat,	135	18.81	81.19	4.30	76.48	.41	6.14	101.84
Mutton, Misc. Cuts.								
Whole side, except kidney and kidney fat,	—	53.48	46.52	16.94	28.67	.91	——	——
Mutton chop, - -	117	44.89	55.11	19.53	34.67	.91	19.53	100.00
Side of Lamb.								
Shoulder, - -	298	51.83	48.17	17.51	29.64	1.02	18.06	100.55
Breast, - - -	299	56.24	43.76	19.16	23.59	1.01	19.04	99.88
Neck, - - -	300	56.69	43.31	17.54	24.81	.96	17.67	100.13
Fore quarter, - -	—	55.06	44.94	18.12	25.82	1.00	——	——
Leg, - - -	296	64.72	35.28	18.91	15.30	1.07	19.74	100.83
Loin, - - -	295	54.82	45.18	19.00	25.12	1.06	19.45	100.45
Hind quarter, -	—	60.88	39.12	18.96	19.09	1.07	——	——
Whole side, except kidney and kidney fat,	—	57.94	42.06	18.53	22.50	1.03	——	——

TABLE 19.

Composition of Mutton and Lamb as received, including both Edible Portion and Refuse.

PORTION TAKEN FOR ANALYSIS.	Lab'rty No.	Refuse.	Edible Portion (including loss)	Edible Portion.				
				Water.	Water-free Substance.	Nutrients.		
						Albs., etc., by diff.	Fat.	Ash.
Side of Mutton.		%	%	%	%	%	%	%
Shoulder, - - - - -	128	16.29	83.71	49.02	34.69	15.14	18.76	.79
Breast, - - - - - -	129	14.95	85.05	31.98	53.07	12.09	40.12	.86
Neck, - - - - - -	130	27.58	72.42	40.33	32.09	11.70	19.82	.57
Rack, - - - - - -	131	19.28	80.72	44.35	36.37	14.84	20.91	.62
Fore quarter, - - - -	—	18.97	81.03	42.31	38.72	13.74	24.22	.76
Leg, - - - - - -	132	18.12	81.88	50.60	31.28	15.00	15.54	.74
Loin, - - - - - -	133	15.75	84.25	41.51	42.74	12.63	29.50	.61
Flank, - - - - - -	134	2.15	97.85	37.90	59.95	15.44	44.06	.45
Hind quarter, - - - -	—	15.65	84.35	46.11	38.24	14.27	23.23	.74
Kidney, and kidney fat, - -	135	——	100.00	18.81	81.19	4.30	76.48	.41
Whole side, except kidney fat, -	—	17.30	82.70	44.23	38.47	14.01	23.71	.75
Side of Lamb.								
Shoulder, - - - - -	298	20.33	79.67	41.29	38.38	13.96	23.61	.81
Breast, - - - - - -	299	19.09	80.91	45.50	35.41	15.50	19.09	.82
Neck, - - - - - -	300	17.67	82.33	46.67	35.66	14.44	20.43	.79
Fore quarter, - - - -	—	18.84	81.16	44.69	36.47	14.71	20.95	.81
Leg, - - - - - -	296	17.70	82.30	53.26	29.04	15.56	12.60	.88
Loin, - - - - - -	295	12.18	87.82	48.14	39.68	16.69	22.06	.93
Hind quarter, - - - -	—	15.65	84.35	51.35	33.00	15.99	16.11	.90
Whole side, except kidney fat, -	—	17.30	82.70	47.92	34.78	15.32	18.61	.85

TABLE 20.

Composition of Side of Mutton and Side of Lamb. Refuse, Edible Portion and Nutrients, expressed in Pounds.

PORTION TAKEN FOR ANALYSIS.	Laboratory No.	Total Weight of Cut.	Refuse.	Edible Portion.	Edible Portion.			
					Water.	Nutrients.		
						Albs., etc. by diff.	Fat.	Ash.
Side of Mutton.		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Shoulder, - - - - -	128	3.17	.52	2.65	1.55	.48	.59	.03
Breast, - - - - - -	129	1.98	.29	1.69	.63	.24	.80	.02
Neck, - - - - - -	130	1.73	.48	1.25	.69	.20	.35	.01
Rack, - - - - - -	131	2.29	.45	1.84	1.01	.34	.48	.01
Fore quarter, - - - -	—	9.17	1.74	7.43	3.88	1.26	2.22	.07
Leg, - - - - - -	132	5.20	.94	4.26	2.62	.79	.81	.04
Loin, - - - - - -	133	3.26	.51	2.75	1.36	.41	.96	.02
Flank, - - - - - -	134	.93	.02	.91	.35	.14	.41	.01
Hind quarter, - - - -	—	9.39	1.47	7.92	4.33	1.34	2.18	.07
Kidney, and kidney fat, - -	135	.39	——	.39	.07	.02	.30	——
Whole side, - - - - -	—	18.95	3.21	15.74	8.28	2.62	4.70	.14
Whole side, except kidney fat, -	—	18.56	3.21	15.35	8.21	2.60	4.40	.14
Side of Lamb.								
Shoulder, - - - - -	298	2.85	.57	2.28	1.18	.40	.68	.02
Breast, - - - - - -	299	3.57	.68	2.89	1.63	.55	.68	.03
Neck, - - - - - -	300	3.03	.53	2.50	1.42	.44	.62	.02
Fore quarter, - - - -	—	9.45	1.78	7.67	4.23	1.39	1.98	.07
Leg, - - - - - -	296	5.50	.97	4.53	2.93	.86	.69	.05
Loin, - - - - - -	295	3.32	.41	2.91	1.60	.55	.73	.03
Hind quarter, - - - -	—	8.82	1.38	7.44	4.53	1.41	1.42	.08
Whole side, except kidney fat, -	—	18.27	3.16	15.11	8.76	2.80	3.40	.15

TABLE 21.

Composition of Water-free Substance of Edible Portion of Veal, Fresh Pork, Chicken, and Turkey.

PORTION TAKEN FOR ANALYSIS.	Laboratory No.	Nitrogen.	Protein (N. × 6.25.)	Fat.	Ash.	Protein, Fat, and Ash.	Albuminoids, etc., (by Difference).
Veal.		%	%	%	%	%	%
Shoulder, - - - -	314	11.80	73.75	21.96	4.23	99.94	73.81
Flank and shoulder, - -	319	9.32	58.25	39.19	3.44	100.88	57.37
Pork.							
Shoulder, - - - -	326	5.28	33.00	66.37	1.93	101.30	31.70
Shoulder, - - - -	333	4.54	28.38	69.56	1.66	99.60	28.78
Shoulder, average, - -	—	4.91	30.69	67.97	1.79	100.45	30.24
Shoulder and chuck ribs, -	302	5.55	34.69	64.11	1.77	100.57	34.12
Shoulder and chuck ribs, -	309	5.75	35.94	63.21	1.94	101.09	34.85
Sh'lder & chuck ribs, average,	—	5.65	35.32	63.66	1.85	100.83	34.49
Poultry.							
Chicken, - - - -	142	14.58	91.14	7.11	5.11	103.36	87.78
Turkey, dark flesh, - -	149*a*	10.89	68.06	33.61	3.46	105.13	62.93
Turkey, white flesh, - -	149*b*	12.59	78.68	17.69	4.03	100.40	78.28
Turkey, dark and white, -	149	11.74	73.37	25.65	3.74	102.76	70.61

TABLE 22.

Composition of Flesh (Edible Portion) of Veal, Fresh Pork, Chicken, and Turkey.

PORTION TAKEN FOR ANALYSIS.	Laboratory No.	Water.	Water-free Substance.	Albuminoids, etc., (by Difference).	Fat.	Ash.	Protein (N. × 6.25).	Water, Protein, Fat, and Ash.
Veal.		%	%	%	%	%	%	%
Shoulder, - - -	314	71.96	28.04	20.69	6.16	1.19	20.68	99.99
Flank and shoulder, -	319	65.64	34.36	19.71	13.47	1.18	20.02	100.31
Pork.								
Shoulder, - - -	326	53.13	46.87	14.86	31.11	.90	15.47	100.61
Shoulder, - - -	333	45.80	54.20	15.60	37.70	.90	15.38	99.78
Shoulder, average, -	—	49.47	50.53	15.23	34.41	.90	15.42	100.20
Sh'lder and chuck ribs,	302	50.28	49.72	16.96	31.88	.88	17.25	100.29
Sh'lder and chuck ribs,	309	51.88	48.12	16.77	30.42	.93	17.29	100.52
Sh'lder and chuck ribs, average, - -	—	51.08	48.92	16.87	31.15	.90	17.27	100.40
Poultry.								
Chicken, - - -	142	72.16	27.84	24.44	1.98	1.42	25.37	100.93
Turkey, dark flesh, -	149*a*	64.63	35.37	22.26	11.89	1.22	24.08	101.82
Turkey, white flesh, -	149*b*	67.57	32.43	25.38	5.74	1.31	25.52	100.14
Turkey, dark and white,	149	66.16	33.84	23.89	8.68	1.27	24.81	100.92

TABLE 23.

Composition of Veal, Fresh Pork, Chicken, and Turkey, as received, including both Edible Portion and Refuse.

PORTION TAKEN FOR ANALYSIS.	Laboratory No.	IN WHOLE SPECIMEN AS TAKEN FOR ANALYSIS.						
				Edible Portion.				
						Nutrients.		
		Refuse.	Edible Portion (including Loss).	Water.	Water-free Substance.	Albuminoids, etc., (by Difference).	Fat.	Ash.
Veal.		%	%	%	%	%	%	%
Shoulder, - - -	314	11.50	88.50	63.68	24.82	18.32	5.45	1.05
Flank and shoulder, -	319	24.30	75.70	49.69	26.01	14.92	10.20	.89
Pork.								
Shoulder, - - -	326	7.10	92.90	49.36	43.54	13.80	28.90	.84
Shoulder, - - -	333	15.30	84.70	38.79	45.91	13.21	31.94	.76
Shoulder, average, -	—	11.20	88.80	44.08	44.72	13.50	30.42	.80
Shoulder and chuck ribs,	302	20.30	79.70	40.07	39.63	13.52	25.41	.70
Shoulder and chuck ribs,	309	15.90	84.10	43.63	40.47	14.10	25.59	.78
Shoulder and chuck ribs, average, - - -	—	18.10	81.90	41.85	40.05	13.81	25.50	.74
Poultry.								
Chicken, - - -	142	38.18	61.82	44.61	17.21	15.11	1.22	.88
Turkey, - - -	149	32.43	67.57	44.71	22.86	16.14	5.86	.86

TABLE 24.

Composition of Water-free Substance of Edible Portion of Preserved and Prepared Meats and Dairy Products.

PORTION TAKEN FOR ANALYSIS.	Laboratory No.	Nitrogen.	Protein (N. × 6.25).	Fat.	Carbohydrates.	Ash.	Protein, Fat, and Ash.	Albuminoids, etc., (by Difference).
Corned Beef.		%	%	%	%	%	%	%
Rump, lean, - -	185*a*	11.06	69.13	21.00	—	9.95	100.08	69.05
Rump, fat, - -	185*b*	.30	1.88	97.32	—	.71	99.91	1.97
Rump, fat and lean,	185	5.07	31.70	63.49	—	4.81	100.00	31.70
Flank, - - -	322	3.70	23.13	72.33	—	4.92	100.38	22.75
Flank, - - -	330	5.94	37.13	57.26	—	7.18	101.57	35.56
Flank, average, -	—	4.82	30.13	64.80	—	6.05	100.98	29.15
Canned, - -	86	9.93	62.06	30.40	—	7.36	99.82	62.24
Canned, - -	331	8.23	51.44	42.04	—	6.99	100.47	50.97
Canned, average, -	—	9.08	56.75	36.22	—	7.18	100.15	56.60
Salted and dried beef,	197	10.83	67.69	10.35	—	15.29	93.33	—
Salted and dried beef,	231	11.41	71.31	10.81	—	17.35	99.47	—
Salted and dried beef, average, - -	—	11.12	69.50	10.58	—	16.32	96.40	—
Salt pork fat, - -	198	.13	.81	94.20	—	4.71	99.72	1.09
Smoked ham, lean, -	140*a*	9.95	62.19	26.60	—	10.04	98.83	—
Smoked ham, lean, -	140*b*	.88	5.50	94.79	—	.95	101.24	—
Smoked ham, lean and fat, - -	140	4.60	28.75	66.81	—	4.68	100.24	—
Sausage.								
Bologna, - -	301	7.92	49.50	41.95	—	8.06	99.51	49.99
Pork, - - -	141	3.89	24.31	72.15	—	3.50	99.96	24.35
Pork, - - -	311	2.89	18.06	73.04	—	4.19	95.29	—
Pork, average, -	—	3.39	21.19	72.59	—	3.85	97.63	—
Dairy Products.								
Cheese, full cream, N. Y. factory, -	187	6.57	41.06	47.51	5.54	5.89	94.46	—
Cheese, full cream, N. Y. factory, -	232	5.99	37.44	54.60	2.01	5.95	97.99	—
Cheese, full cream, N. Y. factory, -	268	6.40	40.00	52.11	2.87	5.02	97.13	—
Average of 3 specimens, - -	—	6.32	39.50	51.41	3.47	5.62	96.53	—
Cheese, "Engl'h dairy," N.Y. factory,	264	6.85	42.81	48.62	1.87	6.70	98.13	—
Cheese, skimmed, -	265	10.45	65.31	11.53	15.26	7.90	84.74	—
Cheese, Neufchatel (American), -	266	6.24	39.00	56.70	.35	3.95	99.65	—
Cheese, Swiss (imported), - -	267	6.55	40.94	51.63	1.21	6.22	98.79	—
Butter, - - -	216	.17	1.06	95.48	—	3.25	99.79	1.27

TABLE 25.

Composition of Flesh (Edible Portion) of Preserved and Prepared Meats and of Dairy Products.

PORTION TAKEN FOR ANALYSIS.	Laboratory No.	Water.	Water-free Substance.	Albuminoids, etc., (by Difference).	Fat.	Carbohydrates.	Ash.	Protein (N. × 6.25).	Water, Protein, Fat and Ash.
Corned Beef.		%	%	%	%	%	%	%	%
Rump, lean, - - -	185*a*	74.57	25.43	17.56	5.34	—	2.53	17.58	100.02
Rump, fat, - - -	185*b*	13.46	86.54	1.70	84.23	—	.61	1.63	99.93
Rump, lean and fat, -	185	58.13	41.87	13.28	26.58	—	2.01	13.28	100.00
Flank, - - - -	322	43.18	56.82	12.92	41.10	—	2.80	13.14	100.22
Flank, - - - -	330	56.51	43.49	15.47	24.90	—	3.12	16.15	100.68
Flank, average, - -		49.84	50.16	14.20	33.00	—	2.96	14.65	100.45
Canned, - - - -	86	53.63	46.37	28.86	14.10	—	3.41	28.78	99.92
Canned, - - - -	331	51.86	48.14	24.53	20.24	—	3.37	24.76	100.23
Canned, average, - -		52.74	47.26	26.70	17.17	—	3.39	26.77	100.07
Salted and dried beef, -	197	59.17	40.83	—	4.22	—	6.24	27.64	97.27
Salted and dried beef, -	231	58.03	41.97	—	4.54	—	7.28	29.93	99.78
Salted and dried beef, average, - - - -		58.60	41.40	—	4.38	—	6.76	28.79	98.53
Salt pork fat, - - -	198	12.14	87.86	.94	82.78	—	4.14	.71	99.77
Smoked ham, lean, - -	140*a*	61.55	38.45	—	10.23	—	3.86	23.91	99.55
Smoked ham, fat, - -	140*b*	8.03	91.97	—	87.18	—	.88	5.06	101.15
Smoked ham, lean and fat,	140	41.49	58.51	—	39.09	—	2.74	16.84	100.16
Sausage.									
Bologna, - - -	301	62.36	37.64	18.82	15.79	—	3.03	18.63	99.81
Pork, - - - - -	141	44.45	55.55	13.52	40.09	—	1.94	13.50	99.98
Pork, - - - - -	311	37.83	62.17	—	45.41	—	2.63	11.23	97.10
Pork, average, - -		41.14	58.86	—	42.75	—	2.29	12.36	98.54
Dairy Products.									
Cheese, full cream, N. Y. factory, - - -	187	36.81	63.19	—	30.02	3.51	3.72	25.94	96.49
Cheese, full cream, N. Y. factory, - - -	232	29.78	70.22	—	38.34	1.41	4.18	26.29	98.59
Cheese, full cream, N. Y. factory, - - -	268	27.00	73.00	—	38.04	2.10	3.67	29.19	97.90
Average of 3 specimens, -		31.20	68.80	—	35.46	2.34	3.86	27.14	97.66
Cheese, "English dairy," N. Y. factory, - -	264	28.63	71.37	—	34.70	1.33	4.78	30.56	98.67
Cheese, skimmed, -	265	41.26	58.74	—	6.77	8.96	4.64	38.37	91.04
Cheese, Neufchatel (Am.),	266	42.70	57.30	—	32.49	.20	2.26	22.35	99.80
Cheese, Swiss (imported),	267	28.95	71.05	—	36.69	.86	4.42	29.08	99.14
Butter, - - - -	216	7.07	92.93	1.15	88.76	—	3.02	.99	99.84

TABLE 26.

Composition of Corned Beef and Smoked Ham as received, including both Edible Portion and Refuse.

PORTION TAKEN FOR ANALYSIS.	Laboratory No.	IN WHOLE SPECIMEN AS TAKEN FOR ANALYSIS.						
				Edible Portion.				
						Nutrients.		
		Refuse.	Edible Portion (including Loss).	Water.	Water-free Substance.	Albuminoids, etc., (by Difference).	Fat.	Ash.
Corned Beef.		%	%	%	%	%	%	%
Rump, - - -	185	5.00	95.00	70.84	24.16	16.69	5.07	2.40
Flank, - - -	322	9.60	90.40	39.04	51.36	11.68	37.15	2.53
Flank, - - -	330	14.60	85.40	48.26	37.14	13.21	21.26	2.67
Smoked ham, -	140	11.40	88.60	36.77	51.83	14.77	34.63	2.43

TABLE 27.

Composition of Water-free Substance of Various Animal Organs and of Hens' Eggs.

PORTION TAKEN FOR ANALYSIS.	Laboratory No.	Nitrogen.	Protein (N. × 6.25).	Fat.	Carbohydrates.	Ash.	Protein, Fat, and Ash.	Albuminoids, etc., (by Difference).
		%	%	%	%	%	%	%
Beef liver, - -	152	10.53	65.82	17.71	11.41	5.06	88.59	—
Beef kidney, - -	178	11.21	70.06	19.56	5.31	5.07	94.69	—
Beef heart, - -	184	5.79	36.19	60.13	—	2.29	98.61	37.58
Beef tongue, - -	183	7.45	46.56	49.32	—	3.01	98.89	47.67
Beef tripe, soused, -	312	13.48	84.25	11.54	—	1.66	97.45	—
Beef marrow, -	177	.36	2.25	95.96	—	1.35	99.56	2.69
Sheep heart, - -	136	8.82	55.13	41.10	—	2.83	99.06	56.07
Sheep lungs, - -	137	13.51	84.44	10.25	—	4.98	99.67	84.77
Sheep liver, - -	138	8.19	51.19	27.95	16.65	4.21	83.35	—
Chicken liver, -	143	11.65	72.84	13.77	7.67	5.72	92.33	—
Chicken heart, -	144	11.80	73.75	19.45	—	5.09	98.29	75.46
Chicken gizzard, -	145	14.38	89.86	5.09	—	5.29	100.24	89.62
Turkey heart, -	146	8.55	53.44	42.15	—	3.06	98.65	54.79
Turkey liver, - -	147	12.03	75.19	17.15	2.10	5.56	97.90	—
Turkey gizzard, -	148	8.80	55.00	38.77	—	2.95	96.72	58.28

TABLE 27.—*(Continued.)*

PORTION TAKEN FOR ANALYSIS.	Laboratory No.	Nitrogen.	Protein (N. × 6.25).	Fat.	Carbohydrates.	Ash.	Protein, Fat, and Ash.	Albuminoids, etc., (by Difference).
Eggs— Yolk.		%	%	%	%	%	%	%
Plymouth Rock, -	150*a*	5.07	31.68	65.21	—	3.32	100.21	31.47
Buff Cochin, - -	196*a*	5.34	33.34	63.90	—	3.41	100.65	32.69
Average, - -	—	5.20	32.51	64.56	—	3.36	100.43	32.08
Eggs— White.								
Plymouth Rock, -	150*b*	13.46	84.12	1.38	—	4.96	90.46	93.66
Buff Cochin, - -	196*b*	13.95	87.20	.37	—	4.30	91.87	95.33
Average, - -	—	13.71	85.66	.87	—	4.63	91.16	94.50
Eggs— Yolk plus White.								
Plymouth Rock, -	150	7.70	48.12	45.23	—	3.81	97.16	50.96
Buff Cochin, - -	196	8.22	51.37	42.66	—	3.70	97.73	53.64
Average, - -	—	7.96	49.74	43.95	—	3.76	97.45	52.29

TABLE 28.

Composition of Flesh (Edible Portion) of Various Animal Organs and Hens' Eggs.

PORTION TAKEN FOR ANALYSIS.	Laboratory No.	Water.	Water-free Substance.	Albuminoids, etc., (by Difference).	Fat.	Carbohydrates.	Ash.	Protein (N. × 6.25).	Water, Protein, Fat, and Ash.
		%	%	%	%	%	%	%	%
Beef liver, -	152	69.52	30.48	—	5.40	3.49	1.54	20.05	96.51
Beef kidney, -	178	75.68	24.32	—	4.76	1.29	1.23	17.04	98.71
Beef heart, -	184	56.48	43.52	16.34	26.18	—	1.00	15.73	99.39
Beef tongue, -	183	63.50	36.50	17.40	18.00	—	1.10	17.00	99.60
Beef tripe, soused	312	83.98	16.02	—	1.85	—	.27	13.50	99.60
Beef marrow, -	177	3.33	96.67	2.59	92.77	—	1.31	2.17	99.58
Sheep heart, -	136	67.43	32.57	18.27	13.38	—	.92	17.96	99.69
Sheep lungs, -	137	74.62	25.38	21.52	2.60	—	1.26	21.43	99.91
Sheep liver, -	138	52.65	47.35	—	13.24	7.88	1.99	24.24	92.12
Chicken liver, -	143	69.26	30.74	—	4.23	2.37	1.76	22.38	97.63
Chicken heart, -	144	71.96	28.04	21.16	5.45	—	1.43	20.68	99.52
Chicken gizzard,	145	72.48	27.52	24.66	1.40	—	1.46	24.73	100.07
Turkey heart, -	146	68.56	31.44	17.23	13.25	—	.96	16.80	99.57
Turkey liver, -	147	69.56	30.44	—	5.23	.63	1.70	22.88	99.37
Turkey gizzard,	148	62.68	37.32	21.75	14.47	—	1.10	20.52	98.77

TABLE 28.—*(Continued.)*

PORTION TAKEN FOR ANALYSIS.	Laboratory No.	Water.	Water-free Substance.	Albuminoids, etc., (by Difference).	Fat.	Carbohydrates.	Ash.	Protein (N. × 6.25).	Water, Protein, Fat, and Ash.
Eggs—Yolk.		%	%	%	%	%	%	%	%
Plymouth Rock,	150*a*	47.75	52.25	16.44	34.07	—	1.74	16.56	100.12
Buff Cochin, -	196*a*	48.98	51.02	16.67	32.61	—	1.74	17.01	100.34
Average, - -	—	48.37	51.63	16.55	33.34	—	1.74	16.78	100.23
Eggs—White.									
Plymouth Rock,	150*b*	86.42	13.58	12.72	.19	—	.67	11.43	98.71
Buff Cochin, -	196*b*	86.67	13.33	12.71	.05	—	.57	11.62	98.91
Average, - -	—	86.55	13.45	12.71	.12	—	.62	11.52	98.81
Eggs—White plus Yolk.									
Plymouth Rock,	150	72.35	27.65	14.09	12.50	—	1.06	13.29	99.20
Buff Cochin, -	196	73.77	26.23	14.09	11.18	—	.96	13.44	99.35
Average, - -	—	73.06	26.94	14.09	11.84	—	1.01	13.37	99.28

TABLE 29.

Composition of Hens' Eggs as received, including both Edible Portion and Refuse.

PORTION TAKEN FOR ANALYSIS.	Laboratory No.	IN WHOLE SPECIMEN AS TAKEN FOR ANALYSIS.						
				Edible Portion.				
						Nutrients.		
		Refuse.	Edible Portion (including Loss).	Water.	Water-free Substance.	Albuminoids, etc., (by Difference).	Fat.	Ash.
Eggs.		%	%	%	%	%	%	%
Plymouth Rock, -	150	13.92	86.08	62.28	23.80	12.13	10.76	.91
Buff Cochin, - -	196	13.43	86.57	63.86	22.71	12.20	9.68	.83
Average of 2 specimens, - -	—	13.68	86.32	63.07	23.25	12.16	10.22	.87

TABLE 30.

Composition of Water-free Substance of Edible Portion of Vegetable Foods.

PORTION TAKEN FOR ANALYSIS.	Laboratory Number.	Nitrogen.	Protein (N. × 6.25).	Fat.	Carbohydrates.	Ash.
		%	%	%	%	%
Wheat bread, bakery (Schaefer's), -	189	2.13	13.31	2.27	83.20	1.22
Wheat bread, bakery (Schaefer's), -	223	2.05	12.81	3.54	82.23	1.42
Wheat bread, average of two, - -		2.09	13.06	2.91	82.71	1.32
Wheat bread, bakery (Stueck's), -	190	2.17	13.56	1.76	83.22	1.46
Wheat bread, bakery (Stueck's), -	222	2.05	12.81	3.65	81.64	1.90
Wheat bread, average, - - -		2.11	13.19	2.70	82.43	1.68
Wheat bread, average of four, - -		2.10	13.13	2.80	82.57	1.50
Wheat bread, home made, - -	213	2.04	12.75	.85	85.54	.86
Graham bread, bakery (Schaefer's), -	193	2.32	14.50	2.07	81.04	2.39
Rye bread, bakery (Schaefer's), -	188	1.93	12.06	.71	85.29	1.94
Soda crackers, - - - - -	191	1.79	11.19	10.16	76.66	1.99
Boston crackers, - - - - -	192	1.87	11.69	10.76	74.92	2.63
Pilot crackers, - - - - -	194	2.15	13.44	4.75	80.65	1.16
Oyster crackers, - - - - -	195	1.88	11.75	4.99	80.62	2.64
Oatmeal crackers, - - - - -	199	1.75	10.94	14.40	73.16	1.50
Graham crackers, - - - - -	200	1.65	10.31	14.25	73.40	2.04
Flour (of bread No. 213), - -	209	2.13	13.31	1.42	84.77	.50
Wheat flour, - - - - - -	321	2.44	15.25	1.42	82.76	.57
Wheat flour, average, - - -		2.29	14.28	1.42	83.76	.54
Oatmeal, - - - - - -	214	2.80	17.50	7.64	72.83	2.03
Oatmeal, - - - - - -	226	2.76	17.25	7.83	72.87	2.05
Oatmeal average, - - - - -		2.78	17.38	7.73	72.85	2.04
Cracked wheat, - - - - -	215	2.10	13.13	1.97	83.32	1.58
Cracked wheat, - - - - -	227	2.15	13.44	1.73	83.21	1.62
Cracked wheat average, - - -		2.13	13.29	1.85	83.26	1.60
Canned corn, - - - - - -	303	1.72	10.75	4.55	79.64	5.06
Canned peas, - - - - -	304	4.04	25.25	1.69	66.87	6.19
Canned tomatoes, - - - -	305	3.11	19.44	2.95	69.79	7.82
Cabbage, - - - - - -	323	3.01	18.81	2.94	70.52	7.73
Cranberries, - - - - - -	327	.53	3.31	7.23	87.73	1.73
Catawba grapes, - - - - -	335	1.05	6.56	6.85	84.30	2.29

TABLE 31.

Composition of Edible Portion of Vegetable Foods.

PORTION TAKEN FOR ANALYSIS.	Laboratory Number.	Water.	Water-free Substance.	Protein (N. × 6.25).	Fat.	Carbohydrates.	Ash.
		%	%	%	%	%	%
Wheat bread, bakery (Schaefer's), - - - - -	189	31.19	68.81	9.16	1.56	57.25	.84
Wheat bread, bakery (Schaefer's), - - - - -	223	32.86	67.14	8.60	2.38	55.21	.95
Wheat bread, average of two,		32.03	67.97	8.88	1.97	56.23	.89
Wheat bread, bakery (Stueck's)	190	33.50	66.50	9.02	1.17	55.34	.97
Wheat bread, bakery (Stueck's)	222	32.28	67.72	8.67	2.47	55.30	1.28
Wheat bread, average of two,		32.89	67.11	8.85	1.82	55.32	1.12
Wheat bread, average of four,		32.46	67.54	8.87	1.89	55.78	1.00
Wheat bread, home made, -	213	31.58	68.42	8.73	.58	58.53	.58
Graham bread, bakery (Schaefer's), - - - - -	193	34.24	65.76	9.50	1.36	53.33	1.57
Rye bread, bakery (Schaefer's)	188	29.97	70.03	8.44	.50	59.73	1.36
Soda crackers, - - -	191	8.01	91.99	10.29	9.35	70.52	1.83
Boston crackers, - - -	192	8.25	91.75	10.73	9.87	68.75	2.40
Pilot crackers, - - -	194	7.90	92.10	12.38	4.38	74.27	1.07
Oyster crackers, - - -	195	3.82	96.18	11.31	4.80	77.53	2.54
Oatmeal crackers, - -	199	4.90	95.10	10.41	13.70	69.59	1.40
Graham crackers, - -	200	5.02	94.98	9.79	13.54	69.71	1.94
Wheat flour (of bread No. 213)	209	14.27	85.73	11.41	1.22	72.67	.43
Wheat flour, - - -	321	11.83	88.17	13.45	1.25	72.97	.50
Average, - - -		13.05	86.95	12.43	1.24	72.82	.46
Oatmeal, - - - - -	214	6.71	93.29	16.32	7.12	67.96	1.89
Oatmeal, - - - - -	226	6.99	93.01	16.04	7.28	67.78	1.91
Oatmeal average of two, -		6.85	93.15	16.18	7.20	67.87	1.90
Cracked wheat, - - -	215	9.78	90.22	11.85	1.78	75.16	1.43
Cracked wheat, - - -	227	11.11	88.89	11.97	1.54	73.94	1.44
Cracked wheat average of two		10.44	89.56	11.91	1.66	74.55	1.44
Canned corn, - - -	303	71.77	28.23	3.03	1.28	22.49	1.43
Canned peas, - - -	304	82.91	17.09	4.32	.29	11.42	1.06
Canned tomatoes, - -	305	94.74	5.26	1.02	.16	3.67	.41
Cabbage, - - - -	323	91.86	8.14	1.53	.24	5.74	.63
Cranberries, - - -	327	87.54	12.46	.41	.90	10.93	.22
Catawba grapes, - - -	335	74.79	25.21	1.65	1.72	21.26	.58

TABLE 32.

COMPOSITION OF FOOD MATERIALS AS FOUND IN THE MARKETS, INCLUDING BOTH EDIBLE PORTION AND REFUSE.

Percentages of Nutrients, Water, and Refuse, and Estimated Potential Energy (Fuel Value) in Specimens Analyzed.

FOOD MATERIALS.		No. of Analyses.	Refuse (Bones, Skin, Shell, etc.)	EDIBLE PORTION.						
				Water.	Nutrients.					Potential Energy in one Pound.
					Total.	Protein.	Fat.	Carbo-hydrates.	Mineral Matters.	
MEATS, ETC.			%	%	%	%	%	%	%	Cal-ories
Beef.										
Neck,	Min.,	3	18.4	47.0	28.9	14.9	11.8	—	.8	800
	Max.,	3	22.9	52.4	32.1	16.2	16.4	—	.9	970
	Avg.,	3	**20.0**	**49.6**	**30.4**	**15.6**	**14.0**	—	**.8**	**880**
Chuck ribs,	Min.,	8	5.4	42.7	30.4	13.5	13.3	—	.6	865
	Max.,	8	19,7	59.7	44.6	16.4	28.6	—	.9	1490
	Avg.,	8	**14.6**	**49.5**	**35.9**	**15.0**	**20.1**	—	**.8**	**1125**
Ribs,	Min.,	4	19.4	36.3	39.7	11.3	26.5	—	.7	1360
	Max.,	4	22.7	40.2	42.3	13.0	29.2	—	.9	1460
	Avg.,	4	**21.0**	**38.2**	**40.8**	**12.2**	**27.9**	—	**.7**	**1405**
Brisket,		1	14.3	40.6	45.1	12.5	31.9	—	.7	1580
Cross ribs,		1	12.2	38.6	49.2	12.0	36.5	—	.7	1765
Shoulder,	Min.,	6	10.7	49.9	27.0	14.8	8.8	—	.7	695
	Max.,	6	15.6	60.6	38.8	18.6	19.2	—	1.0	1155
	Avg.,	6	**12.6**	**55.8**	**31.6**	**17.0**	**13.7**	—	**.9**	**895**
Shin,		1	40.1	44.2	15.7	13.6	1.4	—	.7	310
Plate,		1	17.9	36.4	45.7	12.6	32.4	—	.7	1600
Navel,		1	11.4	42.2	46.4	13,4	32.3	—	.7	1610
Sirloin,	Min.,	4	13.0	42,8	29.7	12.5	14.0	—	.7	920
	Max.,	4	27.3	52.6	35.0	19.1	18.7	—	1.2	1075
	Avg.,	4	**19.5**	**48.3**	**32.2**	**15.0**	**16.4**	—	**.8**	**970**
Socket,		1	35.8	36.7	27.5	10.7	16.1	—	.7	880
Rump,	Min.,	2	6.5	33.7	40.9	12.3	25.1	—	.6	1340
	Max.,	2	16.2	52.6	50.1	15.0	37.2	—	.8	1800
	Avg.,	2	**11.3**	**43.2**	**45.5**	**13.7**	**31.1**	—	**.7**	**1570**
Round, first cut,		1	7.8	60.9	31.3	18.0	12.3	—	1.0	855
Round, second cut,		1	32.1	47.2	20.7	14.0	5.8	—	.9	505
Leg,		1	62.2	27.3	10.5	7.9	2.1	—	.5	235
Top of sirloin,		1	3.2	40.9	55.9	12.9	42.3	—	.7	2025
Flank,		1	11.5	24.3	64.2	10.6	53.0	—	.6	2435
Fore quarter,		—	18.5	44.1	37.4	14.1	22.5	—	.8	1210
Hind quarter,		—	20.2	44.4	35.4	13.6	21.0	—	.8	1140
Side without kidney fat,		—	19.2	44.3	36.5	13.9	21.8	—	.8	1180
Veal.										
Shoulder,		1	11.5	63.7	24.8	18.3	5.5	—	1.0	570
Shoulder and flank,		1	24.3	49.7	26.0	14.9	10.2	—	.9	715

TABLE 32.—*(Continued.)*

Food Materials.	No. of Analyses.	Refuse (Bones, Skin, Shell, etc.)	Edible Portion.						
			Water.	Nutrients.					Potent'l Energy in one Pound.
				Total.	Protein.	Fat.	Carbo-hydrates.	Mineral Matters.	
Mutton.		%	%	%	%	%	%	%	Cal.
Shoulder, - - - - -	1	16.3	49.0	34.7	15.1	18.8	—	.8	1075
Breast, - - - - -	1	14.9	32.0	53.1	12.1	40.1	—	.9	1915
Neck, - - - - -	1	27.6	40.3	32.1	11.7	19.8	—	.6	1055
Rack, - - - - -	1	19.3	44.3	36.4	14.9	20.9	—	.6	1160
Leg, - - - - -	1	18.1	50.6	31.3	15.0	15.6	—	.7	935
Loin, - - - - -	1	15.8	41.5	42.7	12.6	29.5	—	.6	1480
Flank, - - - - -	1	2.1	37.9	60.0	15.4	44.1	—	.5	2145
Fore quarter, - - -	–	19.0	42.3	38.7	13.7	24.2	—	.8	1275
Hind quarter, - - -	–	15.7	46.1	38.2	14.3	23.2	—	.7	1245
Side without kidney fat, -	–	17.3	44.2	38.5	14.0	23.7	—	.8	1260
Lamb.									
Shoulder, - - - - -	1	20.3	41.3	38.4	14.0	23.6	—	.8	1255
Breast, - - - - -	1	19.1	45.5	35.4	15.5	19.1	—	.8	1095
Neck, - - - - -	1	17.7	46.7	35.6	14.4	20.4	—	.8	1130
Leg, - - - - -	1	17.7	53.3	29.0	15.5	12.6	—	.9	820
Loin, - - - - -	1	12.2	48.1	39.7	16.7	22.1	—	.9	1245
Fore quarter, - - -	–	18.8	44.7	36.5	14.7	21.0	—	.8	1160
Hind quarter, - - -	–	15.7	51.3	33.0	16.0	16.1	—	.9	975
Side without kidney fat, -	–	17.3	47.9	34.8	15.3	18.6	—	.9	1070
Pork.									
Shoulder roast, - Min.,	4	7.1	38.8	39.6	13.2	25.4	—	.7	1325
Max.,	4	20.3	49.4	45.9	14.1	28.9	—	.8	1590
Avg.,	4	**14.6**	**43.0**	**42.4**	**13.6**	**28.0**	—	**.8**	**1435**
Poultry, Etc.									
Chicken, - - - - -	1	38.2	44.6	17.2	15.1	1.2	—	.9	330
Turkey, - - - - -	1	32.4	44.7	22.9	16.1	5.9	—	.9	550
Hens' eggs in shell, Min.,	2	13.4	62.3	22.7	12.1	9.7	—	.8	635
Max.,	2	13.9	63.9	23.8	12.2	10.8	—	.9	680
Avg.,	2	**13.7**	**63.1**	**23.2**	**12.1**	**10.2**	—	**.9**	**655**
Preserved Meats.									
Corned beef, rump, - -	1	5.0	70.8	24.2	16.7	5.1	—	2.4	525
Corned beef, flank, Min.,	2	9.6	39.0	37.1	11.7	21.2	—	2.5	1140
Max.,	2	14.6	48.3	51.4	13.2	37.2	—	2.7	1785
Avg.,	2	**12.1**	**43.7**	**44.2**	**12.4**	**29.2**	—	**2.6**	**1460**
Ham, salted and smoked, -	1	11.4	36.8	51.8	14.8	34.6	—	2.4	1735
FISH, SHELL FISH, ETC.									
Fresh Fish.									
Sturgeon, section, - -	1	14.4	67.4	18.2	15.4	1.6	—	1.2	355
Red-horse, entrails removed,	1	52.5	37.3	10.2	8.5	1.1	—	.6	205
Herring, whole, - -	1	46.0	37.3	16.7	10.0	5.9	—	.8	435

TABLE 32.—*(Continued.)*

Food Materials.		No. of Analyses.	Refuse (Bones, Skin, Shell, etc.)	Edible Portion.							
				Water.	Nutrients.						Potent'l Energy in one Pound.
					Total.	Protein.	Fat.	Carbo-hydrates.	Mineral Matters.		
Fresh Fish.			%	%	%	%	%	%	%		Cal.
Alewife, whole,	Min.,	2	49.4	36.9	12.2	9.5	1.9	—	.8		255
	Max.,	2	49.5	38.3	13.7	9.9	3.0	—	.8		310
	Avg.,	2	**49.5**	**37.5**	**13.0**	**9.7**	**2.5**	—	**.8**		**285**
Shad, whole, -	Min.,	7	44.4	30.3	10.9	7.4	2.9	—	.6		260
	Max.,	7	58.8	39.5	18.6	10.5	7.3	—	.8		505
	Avg.,	7	**50.1**	**35.2**	**14.7**	**9.2**	**4.8**	—	**.7**		**375**
Smelt, whole, -	Min.,	2	34.8	39.9	11.1	9.6	.8	—	.7		215
	Max.,	2	49.0	52.3	12.9	10.4	1.2	—	1.3		245
	Avg.,	2	**41.9**	**46.1**	**12.0**	**10.0**	**1.0**	—	**1.0**		**230**
White fish, whole, - -		1	53.5	32.5	14.0	10.3	3.0	—	.7		320
Ciscoe, whole, - - -		1	42.7	43.6	13.7	11.0	2.0	—	.7		290
California salmon, section,	Min.,	2	—	57.9	31.8	16.1	14.8	—	.9		925
	Max.,	2	10.3	62.7	37.3	17.0	19.2	—	1.1		1125
	Avg.,	2	**5.2**	**60.3**	**34.5**	**16.5**	**17.0**	—	**1.0**		**1025**
Salmon, whole,	Min.,	4	30.8	36.9	23.6	13.3	7.9	—	.9		610
	Max.,	4	39.5	45.0	24.3	15.2	10.0	—	1.0		670
	Avg.,	4	**35.3**	**40.6**	**24.1**	**14.3**	**8.8**	—	**1.0**		**635**
Salmon, entrails removed, -		1	23.8	51.2	25.0	14.6	9.5	—	.9		675
Lake trout, whole, - -		1	56.3	30.0	13.7	7.7	5.4	—	.6		370
Lake trout, entrails removed,		1	35.2	45.0	19.8	12.4	6.6	—	.8		510
Brook trout, whole,	Min.,	3	45.2	38.6	11.0	9.2	.4	—	.5		225
	Max.,	3	50.1	43.8	12.3	10.2	1.5	—	.7		255
	Avg.,	3	**48.1**	**40.4**	**11.5**	**9.8**	**1.1**	—	**.6**		**230**
Pickerel, whole,	Min.,	2	45.4	40.8	10.5	9.7	.2	—	.6		190
	Max.,	2	48.7	43.6	11.0	10.0	.3	—	.7		200
	Avg.,	2	**47.1**	**42.2**	**10.7**	**9.8**	**.2**	—	**.7**		**195**
Pike, whole, - - -		1	42.7	45.7	11.6	10.7	.3	—	.6		210
Muscalonge, whole, - -		1	49.2	38.7	12.1	10.0	1.3	—	.8		240
Eel, salt water, dressed,	Min.,	2	19.0	54.9	21.6	14.3	6.4	—	.7		535
	Max.,	2	21,4	59.4	23.7	14.9	8.1	—	.9		620
	Avg.,	2	**20.2**	**57.2**	**22.6**	**14.6**	**7.2**	—	**.8**		**575**
Mullet, whole, - - -		1	57.9	31.5	10.6	8.1	2.0	—	.5		235
Mackerel, whole,	Min.,	5	33.8	35.8	12.2	8.4	1.4	—	.6		300
	Max.,	5	57.9	48.5	23.8	12.1	10.7	—	1.0		675
	Avg.,	5	**44.6**	**40.4**	**15.0**	**10.0**	**4.3**	—	**.7**		**370**
Mackerel, entrails removed,		1	40.7	43.7	15.6	11,4	3.5	—	.7		360
Spanish mackerel, whole, -		1	34.6	44.5	20.9	13.7	6.2	—	1.0		515
Pampano, whole,	Min.,	2	42.4	38.8	11.2	9.9	.8	—	.5		220
	Max.,	2	48.6	40.2	18.8	10.5	7.8	—	.5		525
	Avg.,	2	**45.5**	**39.5**	**15.0**	**10.2**	**4.3**	—	**.5**		**370**
Blue fish, entrails removed,		1	48.6	40.3	11.1	9.8	.6	—	.7		205
Butter fish, whole, - -		1	42.8	40.1	17.1	10.2	6.3	—	.6		455
Black bass, whole,	Min.,	2	53.6	34.6	9.4	8.5	.4	—	.5		175
	Max.,	2	56.0	34.7	11.7	10.0	1.1	—	.6		230
	Avg.,	2	**54.8**	**34.6**	**10.6**	**9.3**	**.8**	—	**.5**		**205**

TABLE 32.—*(Continued.)*

FOOD MATERIALS.	No. of Analyses.	Refuse (Bones, Skin, Shell, etc.).	EDIBLE PORTION.						Potent'l Energy in one Pound.
			Water.	Nutrients.					
				Total.	Protein.	Fat.	Carbo-hydrates.	Mineral Matters.	
Fresh Fish.		%	%	%	%	%	%	%	Cal.
Yellow perch, whole, -	1	62.7	30.0	7.3	6.7	.2	—	.4	135
Yellow perch, dressed, -	1	35.1	50.7	14.2	12.6	.7	—	.9	265
Wall-eyed pike, whole, -	1	57.2	34.1	8.7	7.9	.2	—	.6	155
Gray pike, whole, - -	1	63.2	29.7	7.1	6.4	.3	—	.4	130
Striped bass, whole, Min.,	5	48.6	32.5	8.7	7.2	.7	—	.5	170
Max.,	5	57.1	39.7	11.7	9.7	1.6	—	.6	240
Avg.,	5	**54.9**	**35.1**	**10.0**	**8.3**	**1.1**	—	**.6**	**200**
Striped bass, entrails removed, - - - -	1	51.2	37.4	11.4	8.7	2.2	—	.5	255
White perch, whole, Min.,	2	61.8	27.8	9.0	6.5	1.0	—	.4	185
Max.,	2	63.2	28.9	9.3	7.8	2.1	—	.5	210
Avg.,	2	**62.5**	**28.4**	**9.1**	**7.2**	**1.5**	—	**.4**	**195**
Sea bass, whole, - -	1	56.1	34.8	9.1	8.3	.2	—	.6	160
Red grouper, entrails removed, - - Min.,	2	55.8	34.8	8.9	8.2	.2	—	.5	160
Max.,	2	55.9	35.3	9.3	8.5	.3	—	.5	170
Avg.,	2	**55.9**	**35.0**	**9.1**	**8.4**	**.2**	—	**.5**	**165**
Red snapper, whole, - -	1	40.0	46.9	13.1	12.0	.4	—	.7	240
Red snapper, entrails removed, - - Min.,	2	45.3	36.8	10.7	9.2	.3	—	.6	200
Max.,	2	52.5	43.7	11.0	10.0	.9	—	.7	210
Avg.,	2	**48.9**	**40.3**	**10.8**	**9.6**	**.6**	—	**.6**	**205**
Porgy, whole, - Min.,	3	57.3	27.8	7.1	6.1	.5	—	.5	135
Max.,	3	65.1	31.1	12.0	8.2	3.4	—	.6	295
Avg.,	3	**60.0**	**29.9**	**10.1**	**7.4**	**2.1**	—	**.6**	**225**
Sheepshead, whole, - -	1	66.0	26.9	7.1	6.4	.2	—	.5	125
Sheapshead, entrails removed,	1	56.5	31.3	12.2	8.8	2.9	—	.5	285
Red bass, whole, - -	1	63.5	29.8	6.7	6.1	.2	—	.4	120
King fish, whole, - -	1	56.6	34.4	9.0	8.1	.4	—	.5	170
Weak fish, whole, - -	1	51.9	38.0	10.1	8.4	1.1	—	.6	200
Black fish, whole, Min.,	2	56.2	29.2	6.7	6.3	.2	—	.2	125
Max.,	2	64.1	33.7	10.1	8.3	1.2	—	.6	205
Avg.,	2	**60.1**	**31.5**	**8.4**	**7.3**	**.7**	—	**.4**	**165**
Black fish, entrails removed, Min.,	2	53.6	33.5	8.7	7.9	.4	—	.4	165
Max.,	2	57.8	36.4	10.0	8.7	.7	—	.6	190
Avg.,	2	**55.7**	**35.0**	**9.3**	**8.3**	**.5**	—	**.5**	**175**
Hake, entrails removed, -	1	52.5	39.5	8.0	7.2	.3	—	.5	145
Cusk, entrails removed, -	1	40.3	49.0	10.7	10.1	.1	—	.5	190
Haddock, entrails removed, Min.,	4	48.0	38.5	8.6	7.8	.1	—	.5	150
Max.,	4	52.9	42.9	9.6	8.9	.2	—	.8	170
Avg.,	4	**51.0**	**40.0**	**9.0**	**8.2**	**.2**	—	**.6**	**160**
Cod, whole, - Min.,	2	48.5	35.1	8.4	7.7	.1	—	.6	145
Max.,	2	56.5	42.3	9.2	8.3	.3	—	.6	165
Avg.,	2	**52.5**	**38.7**	**8.8**	**8.0**	**.2**	—	**.6**	**155**

TABLE 32.—*(Continued.)*

FOOD MATERIALS.			No. of Analyses.	Refuse (Bone, Skin, Shell, etc.)	EDIBLE PORTION.						
					Water.	Nutrients.					Potent'l Energy in one Pound.
						Total.	Protein.	Fat.	Carbo-hydrates.	Mineral Matters.	
Fresh Fish.				%	%	%	%	%	%	%	Cal.
Cod, dressed, -	Min.,		3	25.5	55.3	11.0	9.9	.2	—	.8	190
	Max.,		3	33.7	62.1	12.4	11.4	.3	—	.9	220
	Avg.,		3	**29.9**	**58.5**	**11.6**	**10.6**	**.2**	—	**.8**	**205**
Tom-cod, whole, - -			1	59.9	32.7	7.4	6.8	.2	—	.4	135
Poldock, dressed, - -			1	28.5	54.3	17.2	15.5	.6	—	1.1	315
Halibut, sections,	Min.,		3	11.2	60.9	16.0	13.4	1.7	—	.7	320
	Max.,		3	23.1	62.6	26.5	16.1	9.4	—	1.0	695
	Avg.,		3	**17.7**	**61.9**	**20.4**	**15.1**	**4.4**	—	**.9**	**465**
Turbot, whole, - - -			1	47.7	37.3	15.0	6.8	7.5	—	.7	440
Flounder, whole,	Min.,		2	56.2	35.8	6.8	6.1	.2	—	.5	120
	Max.,		2	57.0	37.0	7.2	6.3	.3	—	.6	130
	Avg.,		2	**56.6**	**36.4**	**7.0**	**6.2**	**.3**	—	**.5**	**125**
Flounder, entrails removed,			1	57.0	35.8	7.2	6.3	.3	—	.6	130
Lamprey eel, whole, - -			1	45.8	38.5	15.7	8.1	7.2	—	.4	455
Skate, lobe of body, - -			1	51.0	40.2	8.8	7.5	.7	—	.6	170
Preserved Fish.		Salt. %									
Salted mackerel, -		7.1	1	33.3	28.1	31.5	14.7	15.1	—	1.7	910
Salted cod,	Min.,	17.2	2	24.3	40.0	17.2	15.7	.3	—	1.2	305
	Max.,	17.3	2	25.5	40.5	18.0	16.4	.4	—	1.2	320
	Avg.,	**17.2**	2	**24.9**	**40.3**	**17.6**	**16.0**	**.4**	—	**1.2**	**315**
Smoked herring, -		6.5	1	44.4	19.2	29.9	20.2	8.8	—	.9	745
Smoked haddock, -		1.4	1	32.2	49.2	17.2	16.1	.1	—	1.0	305
Smoked halibut,	Min.,	12.0	2	5.9	44.9	33.0	16.7	13.6	—	1.9	920
	Max.,	12.1	2	8.0	47.0	37.1	21.6	14.4	—	1.9	975
	Avg.,	**12.1**	2	**6.9**	**46.0**	**35.0**	**19.1**	**14.0**	—	**1.9**	**945**
Shell Fish, Etc.											
Oysters in shell,	Min.,		34	76.1	9.2	1.0	.5	.1	.2	.1	—
	Max.,		34	88.8	22.8	4.6	2.1	.4	1.3	.7	—
	Avg.,		34	**82.4**	**15.3**	**2.3**	**1.1**	**.2**	**.6**	**.4**	**40**
Long clams in shell,	Min.,		4	42.1	46.4	7.5	4.4	.5	.9	1.2	120
	Max.,		4	46.1	49.9	8.5	5.1	.7	1.4	1.6	145
	Avg.,		4	**43.6**	**48.4**	**8.0**	**4.8**	**.6**	**1.1**	**1.5**	**135**
Round clams in shell, -			1	68.3	27.3	4.4	2.1	.1	1.3	.9	65
Mussels in shell, - -			1	49.3	42.7	8.0	4.4	.6	2.1	.9	145
Lobster in shell,	Min.,		4	47.5	25.1	5.5	4.1	.5	—	.6	125
	Max.,		4	69.4	44.3	8.2	6.5	.9	—	.8	160
	Avg.,		4	**62.1**	**31.1**	**6.8**	**5.4**	**.7**	—	**.7**	**130**
Crab in shell, - - -			1	55.8	34.1	10.1	7.9	.9	—	1.3	185
Terrapin in shell, - -			1	79.0	15.7	5.3	4.4	.7	—	.2	110
Green turtle in shell, - -			1	76.0	19.2	4.8	4.4	.1	—	.3	85

TABLE 33.

COMPOSITION OF FOOD MATERIALS.—EDIBLE PORTION.

Percentages of Nutrients, Water, etc., and Estimated Potential Energy in Specimens Analyzed.

FOOD MATERIALS.		No. of Analyses.	Water.	NUTRIENTS.					Potential Energy in one Pound.
				Total.	Protein.	Fat.	Carbo-hydrates.	Mineral Matters.	
MEATS, ETC.			%	%	%	%	%	%	Cal.
Beef.									
Neck,	Min.,	3	60.6	35.5	18.3	14.5	—	1.0	985
	Max.,	3	64.5	39.4	20.2	20.1	—	1.1	1190
	Avg.,	3	**62.0**	**38.0**	**19.5**	**17.5**	—	**1.0**	**1100**
Chuck ribs,	Min.,	8	51.3	33.8	16.0	14.7	—	.7	960
	Max.,	8	66.2	48.7	20.4	32.0	—	1.2	1650
	Avg.,	8	**58.0**	**42.0**	**17.6**	**23.5**	—	**.9**	**1320**
Ribs,	Min.,	5	46.2	50.1	14.6	32.9	—	.8	1690
	Max.,	5	49.9	53.8	16.1	37.1	—	1.1	1860
	Avg.,	5	**48.1**	**51.9**	**15.4**	**35.6**	—	**.9**	**1790**
Brisket,		1	47.4	52.6	14.6	37.2	—	.8	1840
Cross ribs,		1	43.9	56.1	13.7	41.6	—	.8	2010
Shoulder,	Min.,	6	56.2	30.8	17.1	10.0	—	.9	790
	Max.,	6	69.2	43.8	21.0	21.6	—	1.2	1300
	Avg.,	6	**63.9**	**36.1**	**19.5**	**15.6**	—	**1.0**	**1020**
Shin,		1	73.8	26.2	22.7	2.3	—	1.2	520
Plate,		1	44.4	55.6	15.4	39.4	—	.8	1950
Navel,		1	47.6	52.4	15.1	36.5	—	.8	1820
Sirloin,	Min.,	4	58.9	39.3	16.9	16.1	—	.9	1090
	Max.,	4	60.7	41.1	22.0	22.9	—	1.4	1290
	Avg.,	4	**60.0**	**40.0**	**18.5**	**20.5**	—	**1.0**	**1210**
Socket,		1	57.1	42.9	16.7	25.2	—	1.0	1375
Rump,	Min.,	2	40.2	43.7	14.7	26.8	—	.8	1430
	Max.,	2	56.3	59.8	16.1	44.3	—	.8	2145
	Avg.,	2	**48.2**	**51.8**	**15.4**	**35.6**	—	**.8**	**1790**
Round,	Min.,	3	66.0	30.5	19.5	8.3	—	1.1	745
	Max.,	3	69.5	34.0	21.5	13.4	—	1.3	930
	Avg.,	3	**68.2**	**31.8**	**20.5**	**10.1**	—	**1.2**	**805**
Leg,		1	72.1	27.9	21.0	5.7	—	1.2	630
Top of sirloin,		1	42.2	57.8	13.3	43.7	—	.8	2090
Flank,		1	27.4	72.6	12.0	59.9	—	.7	2750
Fore quarter,		—	54.1	45.9	17.3	27.7	—	.9	1490
Hind quarter,		—	55.7	44.3	17.1	26.3	—	.9	1430
Side without kidney fat,		—	54.8	45.2	17.2	27.1	—	.9	1465
Liver,		1	69.5	30.5	20.1	5.4	3.5	1.5	665
Kidney,		1	75.7	24.3	17.0	4.8	1.3	1.2	545
Heart,		1	56.5	43.5	16.3	26.2	—	1.0	1410
Tongue,		1	63.5	36.5	17.4	18.0	—	1.1	1085
Kidney fat,		1	4.3	95.7	.9	94.6	—	.2	4010
Marrow (leg bone),		1	3.3	96.7	2.6	92.8	—	1.3	3965

TABLE 33.—*(Continued.)*

FOOD MATERIALS.		No. of Analyses.	Water.	NUTRIENTS.					Potential Energy in one Pound.
				Total.	Protein.	Fat.	Carbo-hydrates.	Mineral Matters.	
Veal.			%	%	%	%	%	%	Cal.
Shoulder,	Min.,	2	65.6	28.0	19.7	6.1	—	1.2	640
	Max.,	2	72.0	34.4	20.7	13.5	—	1.2	935
	Avg.,	2	**68.8**	**31.2**	**20.2**	**9.8**	—	**1.2**	**790**
Mutton.									
Shoulder,		1	58.6	41.4	18.1	22.4	—	.9	1280
Breast,		1	37.6	62.4	14.2	47.2	—	1.0	2255
Rack,		1	54.9	45.1	18.4	25.9	—	.8	1435
Neck,		1	55.7	44.3	16.2	27.3	—	.8	1455
Leg,		1	61.8	38.2	18.3	19.0	—	.9	1140
Loin,		1	49.3	50.7	15.0	35.0	—	.7	1755
Flank,		1	38.7	61.3	15.8	45.0	—	.5	2195
Fore quarter,		–	55.2	47.8	17.0	29.9	—	.9	1580
Hind quarter,		–	54.7	45.3	16.9	27.5	—	.9	1475
Side without kidney fat,		–	53.5	46.5	16.9	28.7	—	.9	1525
Lamb.									
Shoulder,		1	51.8	48.2	17.5	29.7	—	1.0	1580
Breast,		1	56.2	43.8	19.2	23.6	—	1.0	1355
Neck,		1	56.7	43.3	17.5	24.8	—	1.0	1375
Leg,		1	64.7	35.3	18.9	15.3	—	1.1	1000
Loin,		1	54.8	45.2	19.0	25.1	—	1.1	1410
Fore quarter,		–	55.1	44.9	18.1	25.8	—	1.0	1425
Hind quarter,		–	60.9	39.1	18.9	19.1	—	1.1	1155
Side without kidney fat,		–	57.9	42.1	18.6	22.5	—	1.0	1295
Liver,		1	52.7	47.3	24.2	13.2	7.9	2.0	1155
Heart,		1	67.4	32.6	18.3	13.4	—	.9	905
Lungs,		1	74.6	25.4	21.5	2.6	—	1.3	510
Pork.									
Shoulder roast,	Min.,	4	45.8	46.9	14.9	30.4	—	.9	1590
	Max.,	4	53.1	54.2	16.9	37.7	—	.9	1880
	Avg.,	4	**50.3**	**49.7**	**16.0**	**32.8**	—	**.9**	**1680**
Poultry, Etc.									
Chicken,		1	72.2	27.8	24.4	2.0	—	1.4	540
Chicken liver,		1	69.3	30.7	22.3	4.2	2.4	1.8	635
Chicken heart,		1	72.0	28.0	21.2	5.4	—	1.4	620
Chicken gizzard,		1	72.5	27.5	24.7	1.4	—	1.4	520
Turkey,		1	66.2	33.8	23.9	8.7	—	1.2	810
Turkey liver,		1	69.6	30.4	22.9	5.2	.6	1.7	655
Turkey heart,		1	68.6	31.4	17.2	13.2	—	1.0	875
Turkey gizzard,		1	62.7	37.3	21.7	14.5	—	1.1	1015
Hens' eggs in shell,	Min.,	27	72.0	24.8	13.8	9.1	—	.7	650
	Max.,	27	75.3	28.0	16.1	12.5	—	1.6	795
	Avg.,	27	**73.8**	**26.2**	**14.9**	**10.5**	—	**.8**	**720**
Preserved Meats.									
Corned beef, rump,		1	58.1	41.9	13.3	26.6	—	2.0	1370
Corned beef, flank,	Min.,	2	43.2	43.5	12.9	24.9	—	2.8	1340
	Max.,	2	56.5	56.8	15.5	41.1	—	3.1	1975
	Avg.,	2	**49.8**	**50.2**	**14.2**	**33.0**	—	**3.0**	**1655**

TABLE 33.—*(Continued.)*

FOOD MATERIALS.		No. of Analyses.	Water.	NUTRIENTS.					Potential Energy in one Pound.
				Total.	Protein.	Fat.	Carbo-hydrates.	Mineral Matters.	
			%	%	%	%	%	%	Cal.
Preserved Meats.									
Corned beef, canned,	Min.,	2	51.9	46.4	24.5	14.1	—	3.4	1130
	Max.,	2	53.6	48.1	28.9	20.2	—	3.4	1310
	Avg.,	2	**52.8**	**47.2**	**26.7**	**17.1**	—	**3.4**	**1220**
Dried beef, - -	Min.,	2	58.0	40.8	27.6	4.2	.2	6.3	740
	Max.,	2	59.2	42.0	29.9	4.6	2.7	7.3	755
	Avg.,	2	**58.6**	**41.4**	**28.8**	**4.4**	**1.4**	**6.8**	**745**
Tripe, soused, - - - -		1	84.0	16.0	13.9	1.8	—	.3	335
Salt pork, fat, - - - -		1	12.1	87.9	.9	82.8	—	4.2	3510
Smoked ham, - - - -		1	41.5	58.5	16.7	39.1	—	2.7	1960
Pork sausage, - -	Min.,	2	37.8	55.5	13.5	40.1	—	1.9	1945
	Max.,	2	44.5	62.2	14.1	45.5	—	2.6	2180
	Avg.,	2	**41.2**	**58.8**	**13.8**	**42.8**	—	**2.2**	**2065**
Bologna sausage, - - -		1	62.4	37.6	18.8	15.8	—	3.0	1015
FISH, SHELL FISH, ETC.									
Fresh Fish.									
Sturgeon, - - - - -		1	78.7	21.3	18.0	1.9	—	1.4	415
Red-horse, - - - -		1	78.6	21.4	17.9	2.3	—	1.2	430
Herring, - - - - -		1	69.0	31.0	18.5	11.0	—	1.5	810
Alewife, - - -	Min.,	2	72.7	24.1	18.8	3.8	—	1.5	510
	Max.,	2	15.9	27.0	19.5	6.0	—	1.5	615
	Avg.,	2	**74.4**	**25.6**	**19.2**	**4.9**	—	**1.5**	**565**
Shad, - - -	Min.,	7	65.3	26.4	17.8	6.5	—	.9	630
	Max.,	7	73.6	34.8	20.0	13.6	—	1.5	940
	Avg.,	7	**70.6**	**29.4**	**18.6**	**9.5**	—	**1.3**	**745**
Smelt, - - -	Min.,	2	78.2	19.8	15.9	1.7	—	1.4	375
	Max.,	2	80.2	21.8	18.8	1.9	—	2.0	420
	Avg.,	2	**79.2**	**20.8**	**17.3**	**1.8**	—	**1.7**	**400**
White fish, - - - -		1	69.8	30.2	22.1	6.5	—	1.6	685
Ciscoe, - - - - -		1	76.1	23.9	19.1	3.6	—	1.2	505
California salmon, -	Min.,	2	62.7	35.5	17.0	16.5	—	1.0	1030
	Max.,	2	64.5	37.3	18.0	19.3	—	1.1	1130
	Avg.,	2	**63.6**	**36.4**	**17.4**	**17.9**	—	**1.1**	**1080**
Salmon, - - -	Min.,	5	61.0	32.9	19.2	12.5	—	1.2	885
	Max.,	5	67.2	39.0	24.5	15.0	—	1.6	1010
	Avg.,	5	**63.6**	**36.4**	**21.6**	**13.4**	—	**1.4**	**965**
Lake trout, - -	Min.,	2	68.8	30.5	17.3	10.2	—	1.2	785
	Max.,	2	69.5	31.2	19.1	12.6	—	1.4	855
	Avg.,	2	**69.1**	**30.9**	**18.2**	**11.4**	—	**1.3**	**820**
Brook trout, - -	Min.,	3	75.8	20.2	18.5	.8	—	1.0	380
	Max.,	3	79.8	24.2	20.0	2.9	—	1.4	495
	Avg.,	3	**77.7**	**22.3**	**19.0**	**2.1**	—	**1.2**	**440**
Pickerel, - - -	Min.,	2	79.5	20.2	18.4	.5	—	1.1	365
	Max.,	2	79.8	20.5	18.9	.5	—	1.2	375
	Avg.,	2	**79.7**	**20.3**	**18.6**	**.5**	—	**1.2**	**365**
Pickerel, pike, - - -		1	79.8	20.2	18.6	.6	—	1.0	370

TABLE 33.—*(Continued.)*

FOOD MATERIALS.		No. of Analyses.	Water.	NUTRIENTS.					Potential Energy in one Pound.
				Total.	Protein.	Fat.	Carbo-hydrates.	Mineral Matters.	
			%	%	%	%	%	%	Cal.
Fresh Fish.									
Muscalonge, - - - -		1	76.3	23.7	19.6	2.5	—	1.6	470
Eel, salt water, - -	Min.,	2	69.8	26.6	17.6	7.9	—	.9	660
	Max.,	2	73.4	30.2	19.0	10.3	—	1.1	790
	Avg.,	2	**71.6**	**28.4**	**19.3**	**9.1**	—	**1.0**	**725**
Mullet, - - - - -		1	74.9	25.1	19.3	4.6	—	1.2	555
Mackerel, - - -	Min.,	6	64.0	21.3	17.5	2.2	—	1.0	430
	Max.,	6	78.7	36.0	19.3	16.3	—	1.5	1025
	Avg.,	6	**73.4**	**26.6**	**18.2**	**7.1**	—	**1.3**	640
Spanish mackerel, - - -		1	68.1	31.9	20.6	9.8	—	1.5	790
Pampano, - -	Min.,	2	67.4	21.8	18.2	1.6	—	1.0	425
	Max.,	2	78.2	32.6	19.2	13.5	—	1.0	910
	Avg.,	2	**72.8**	**27.2**	**18.6**	**7.6**	—	**1.0**	**665**
Blue fish, - - - - -		1	78.5	21.5	19.0	1.2	—	1.3	405
Butter fish, - - - -		1	70.0	30.0	17.8	11.0	—	1.2	795
Black bass, - -	Min.,	2	74.8	21.4	19.2	1.0	—	1.2	400
	Max.,	2	78.6	25.2	21.5	2.5	—	1.2	505
	Avg.,	2	**76.7**	**23.3**	**20.4**	**1.7**	—	**1.2**	**450**
Yellow perch, - -	Min.,	2	78.1	19.6	17.9	.6	—	1.1	360
	Max.,	2	80.4	21.9	19.5	1.1	—	1.3	410
	Avg.,	2	**79.3**	**20.7**	**18.7**	**.8**	—	**1.2**	**380**
Wall-eyed pike, - - -		1	79.7	20.3	18.4	.5	—	1.4	365
Gray pike, - - - -		1	80.8	19.2	17.3	.8	—	1.1	355
Striped bass, - -	Min.,	6	75.8	20.3	16.7	1.6	—	.9	405
	Max.,	6	79.7	24.2	18.8	4.6	—	1.4	525
	Avg.,	6	**77.7**	**22.3**	**18.3**	**2.8**	—	**1.2**	**460**
White perch, - -	Min.,	2	75.6	24.2	17.6	2.5	—	1.1	485
	Max.,	2	75.8	24.4	20.4	5.6	—	1.3	565
	Avg.,	2	**75.7**	**24.3**	**19.0**	**4.1**	—	**1.2**	**525**
Sea bass, - - - - -		1	79.3	20.7	18.8	.5	—	1.4	370
Grouper, - - -	Min.,	2	79.0	20.0	18.5	.5	—	1.1	365
	Max.,	2	80.0	21.0	19.2	.7	—	1.1	385
	Avg.,	2	**79.4**	**20.6**	**18.9**	**.6**	—	**1.1**	**375**
Red snapper, - -	Min.,	3	77.3	20.2	18.3	.5	—	1.3	360
	Max.,	3	79.8	22.7	19.9	1.9	—	1.3	440
	Avg.,	3	**78.5**	**21.5**	**19.2**	**1.0**	—	**1.3**	**400**
Porgy, - - -	Min.,	3	72.0	20.3	17.5	1.5	—	1.4	390
	Max.,	3	79.7	28.0	19.3	7.9	—	1.4	685
	Avg.,	3	**75.0**	**25.0**	**18.5**	**5.1**	—	**1.4**	**560**
Sheepshead, - -	Min.,	2	72.0	20.9	18.9	.7	—	1.1	380
	Max.,	2	79.1	28.0	20.2	6.7	—	1.3	660
	Avg.,	2	**75.6**	**24.4**	**19.5**	**3.7**	—	**1.2**	**520**
Red bass, - - - - -		1	81.6	18.4	16.7	.5	—	1.2	230
King fish, - - - -		1	79.2	20.8	18.7	.9	—	1.2	385
Weak fish, - - - -		1	79.0	21.0	17.4	2.4	—	1.2	425
Black fish, - -	Min.,	4	77.0	18.6	17.4	.6	—	.7	350
	Max.,	4	81.0	23.0	19.0	2.8	—	1.4	470
	Avg.,	4	**79.1**	**20.9**	**18.5**	**1.3**	—	**1.1**	**400**

TABLE 33.—*(Continued.)*

FOOD MATERIALS.		Salt.	No. of Analyses.	Water.	NUTRIENTS.					Potential Energy in one Pound.
					Total.	Protein.	Fat.	Carbo-hydrates.	Mineral Matters.	
		%		%	%	%	%	%	%	Cal.
Fresh Fish.										
Hake, - - - - -			1	83.1	16.9	15.2	.7	—	1.0	310
Cusk, - - - - -			1	82.0	18.0	16.9	.2	—	.9	325
Haddock, - - -	Min.,		4	80.3	17.4	15.9	.1	—	1.0	305
	Max.,		4	82.6	19.7	18.4	.4	—	1.6	350
	Avg.,		4	**81.7**	**18.3**	**16.8**	**.3**	—	**1.2**	**325**
Cod, - - -	Min.,		5	80.7	16.5	15.0	.3	—	1.0	285
	Max.,		5	83.5	19.3	17.6	.5	—	1.3	340
	Avg.,		5	**82.6**	**17.4**	**15.8**	**.4**	—	**1.2**	**310**
Tom-cod, - - - - -			1	81.5	18.5	17.1	.4	—	1.0	335
Pollock, - - - - -			1	76.0	24.0	21.7	.8	—	1.5	440
Halibut, - - -	Min.,		3	70.1	20.8	17.5	2.2	—	.9	420
	Max.,		3	79.2	29.9	19.4	10.6	—	1.2	785
	Avg.,		3	**75.4**	**24.6**	**18.3**	**5.2**	—	**1.1**	**560**
Turbot, - - - - -			1	71.4	28.6	12.9	14.4	—	1.3	850
Flounder, - - -	Min.,		3	83.4	15.0	12.9	.4	—	1.2	275
	Max.,		3	85.0	16.6	14.7	.7	—	1.3	300
	Avg.,		3	**84.2**	**15.8**	**13.9**	**.6**	—	**1.3**	**285**
Lamprey eel, - - - -			1	71.1	28.9	14.9	13.3	—	.7	840
Skate, - - - - -			1	82.2	17.8	15.3	1.4	—	1.1	345
Preserved Fish.										
Dessicated cod, - - -		2.9	1	15.2	81.9	74.6	1.9	—	5.4	1470
Salt cod, - -	Min.,	22.7	2	53.5	23.0	21.2	.3	—	1.6	405
	Max.,	23.4	2	53.6	23.8	21.7	.4	—	1.6	420
	Avg.,	**23.0**	2	**53.6**	**23.4**	**21.4**	**.4**	—	**1.6**	**410**
Boned cod, - - -		21.5	1	54.3	24.2	22.2	.3	—	1.7	425
Salt mackerel, - - -		10.6	1	42.2	47.2	22.1	22.6	—	2.5	1365
Smoked haddock, - -		.2	11	72.5	25.4	23.7	.2	—	1.5	450
Smoked halibut,	Min.,	12.9	2	47.7	35.9	18.2	14.4	—	2.0	995
	Max.,	13.1	2	51.1	39.4	23.0	15.6	—	2.1	1035
	Avg.,	**12.9**	2	**49.4**	**37.7**	**20.6**	**15.1**	—	**2.0**	**1020**
Canned mackerel, - -		1.9	1	68.2	29.9	19.9	8.7	—	1.3	735
Canned salmon,	Min.,	.4	3	57.6	33.6	19.2	11.1	—	1.3	865
	Max.,	2.2	3	65.9	42.0	21.3	21.5	—	1.4	1265
	Avg.,	**1.0**	3	**61.9**	**37.1**	**20.1**	**15.7**	—	**1.3**	**1035**
Canned sardines, - -		—	1	56.4	43.6	25.3	12.7	—	5.6	1005
Canned tunny, - - -		—	1	72.7	27.3	21.5	4.1	—	1.7	575
Canned salt mackerel,	Min.,	9.4	2	43.2	45.2	16.9	24.8	—	2.5	1375
	Max.,	11.2	2	43.6	47.3	17.7	27.9	—	2.7	1490
	Avg.,	**10.3**	2	**43.4**	**46.3**	**17.3**	**26.3**	—	**2.6**	**1430**
Canned smoked haddock, -		5.6	1	68.7	25.7	21.8	2.3	—	1.6	505
Shell Fish, Etc.										
Oysters in shell, -	Min.,		34	81.7	8.6	4.2	.6	1.8	1.2	135
	Max.,		34	91.4	18.3	8.5	1.7	6.7	2.8	345
	Avg.,		34	**87.1**	**12.9**	**6.1**	**1.2**	**3.6**	**2.0**	**230**

TABLE 33.—*(Continued.)*

FOOD MATERIALS.		No. of Analyses.	Water.	NUTRIENTS.					Potential Energy in one Pound.
				Total.	Protein.	Fat.	Carbo-hydrates.	Mineral Matters.	
Shell Fish, Etc.			%	%	%	%	%	%	Cal.
Oysters, "solids,"	Min.,	4	85.2	11.6	5.9	1.5	3.2	.8	230
	Max.,	4	88.4	14.8	6.6	1.8	5.6	1.1	300
	Avg.,	4	**87.2**	**12.8**	**6.3**	**1.6**	**4.0**	**.9**	**260**
Canned oysters,	Min.,	3	84.6	14.0	7.0	2.0	4.1	1.3	285
	Max.,	3	86.0	15.4	8.0	2.2	5.2	1.4	310
	Avg.,	3	**85.3**	**14.7**	**7.4**	**2.1**	**3.9**	**1.3**	**300**
Long clams from shell,	Min.,	4	85.0	13.9	8.1	1.0	1.5	2.1	225
	Max.,	4	86.1	15.0	9.0	1.2	2.5	3.0	255
	Avg.,	4	**85.8**	**14.2**	**8.6**	**1.0**	**2.0**	**2.6**	**240**
Long clams, canned,		1	84.5	15.5	9.0	1.3	2.9	2.3	275
Round clams from shell,		1	86.2	13.8	6.5	.4	4.2	2.7	215
Round clams, canned,		1	83.0	17.0	10.4	.8	3.0	2.8	285
Scallops,	Min.,	2	77.8	17.2	14.4	—	1.1	1.3	310
	Max.,	2	82.8	22.2	15.1	.3	5.7	1.5	385
	Avg.,	2	**80.3**	**19.7**	**14.7**	**.2**	**3.4**	**1.4**	**345**
Mussels from shell,		1	84.2	15.8	8.7	1.1	4.1	1.9	285
Lobster from shell,	Min.,	4	79.2	15.7	12.3	1.5	—	1.6	310
	Max.,	4	84.3	20.8	17.8	2.5	—	1.9	395
	Avg.,	4	**81.8**	**18.2**	**14.6**	**1.9**	—	**1.7**	**350**
Lobster, canned,	Min.,	2	76.2	20.6	17.4	.5	—	2.2	340
	Max.,	2	79.4	23.8	20.0	1.7	—	2.8	445
	Avg.,	2	**77.7**	**22.3**	**18.7**	**1.1**	—	**2.5**	**395**
Cray fish,		1	81.2	18.8	17.0	.5	—	1.3	335
Crab,		1	77.1	22.9	17.8	2.0	—	3.1	415
Crabs, canned,	Min.,	2	79.0	19.0	16.5	.8	—	1.8	340
	Max.,	2	81.0	21.0	16.7	2.3	—	2.1	410
	Avg.,	2	**80.0**	**20.0**	**16.5**	**1.5**	—	**2.0**	**370**
Shrimp,		1	70.8	29.2	25.6	1.0	—	2.6	520
Terrapin,		1	74.5	25.5	21.0	3.5	—	1.0	540
Green turtle,		1	79.8	20.2	18.5	.5	—	1.2	365
DAIRY PRODUCTS, ETC.									
Milk,		—	87.0	13.0	3.6	4.0	4.7	.7	325
Butter,		—	10.5	89.5	1.0	85.0	.5	3.0	3615
Cheese, full cream,	Min.,	5	27.0	63.2	26.0	30.0	.8	3.7	1815
	Max.,	5	36.8	73.0	30.6	38.3	3.5	4.8	2185
	Avg.,	5	**30.2**	**69.8**	**28.3**	**35.5**	**1.8**	**4.2**	**2070**
Cheese, skim-milk,		1	41.3	58.7	38.4	6.8	8.9	4.6	1165
Oleomargarine,		—	11.0	89.0	.6	85.0	.4	3.0	3605
VEGETABLE FOODS.									
Potatoes,*	Min.,	12	75.4	17.8	1.1	—	14.3	.8	315
	Max.,	12	82.2	24.6	3.0	.1	21.2	1.2	445
	Avg.,	12	**78.9**	**21.1**	**2.1**	**.1**	**17.9**	**1.0**	**375**
Sweet potatoes,*	Min.,	6	66.0	25.6	.5	.3	18.6	.7	465
	Max.,	6	74.4	34.0	3.6	.6	32.2	1.3	620
	Avg.,	6	**71.1**	**28.9**	**1.5**	**.4**	**26.0**	**1.0**	**530**

TABLE 33.—*(Continued.)*

Food Materials.		No. of Analyses.	Water.	Nutrients.					Potential Energy in one Pound.
				Total.	Protein.	Fat.	Carbo-hydrates.	Mineral Matters.	
Vegetable Foods.			%	%	%	%	%	%	Cal.
Red beets,*	Min.,	9	85.5	7.8	1.1	.1	4.5	.7	130
	Max.,	9	92.2	14.5	1.8	.3	13.0	1.6	250
	Avg.,	9	**88.5**	**11.5**	**1.5**	**.1**	**8.8**	**1.1**	**195**
Turnips,*	Min.,	7	87.1	7.6	.8	.1	5.0	.7	135
	Max.,	7	92.4	12.9	1.4	.3	10.5	1.4	225
	Avg.,	7	**89.4**	**10.6**	**1.2**	**.2**	**8.2**	**1.0**	**185**
Carrots,*	Min.,	8	86.5	8.9	.8	.2	6.0	.6	155
	Max.,	8	91.1	13.5	2.0	.7	12.7	1.3	235
	Avg.,	8	**88.6**	**11.4**	**1.1**	**.4**	**8.9**	**1.0**	**205**
Onions,*	Min.,	6	81.5	6.5	.8	.2	4.2	.4	120
	Max.,	6	93.5	18.5	2.3	.4	15.5	.7	335
	Avg.,	6	**87.6**	**12.4**	**1.4**	**.3**	**10.1**	**.6**	**225**
Squash, flesh,*	Min.,	3	85.3	10.3	.7	—	8.1	.5	190
	Max.,	3	89.7	14.7	1.1	.3	13.2	.9	265
	Avg.,	3	**88.1**	**11.9**	**.9**	**.2**	**10.1**	**.7**	**215**
Pumpkin, flesh,*	Min.,	2	92.4	5.6	.9	.1	3.9	.6	95
	Max.,	2	94.4	7.6	1.0	.1	5.9	.7	130
	Avg.,	2	**93.4**	**6.6**	**.9**	**.1**	**4.9**	**.7**	**110**
Cucumber,*	Min.,	2	95.7	3.7	.8	.2	2.3	.5	65
	Max.,	2	96.3	4.3	.8	.2	2.8	.5	75
	Avg.,	2	**96.0**	**4.0**	**.8**	**.2**	**2.5**	**.5**	**70**
Cabbage, entire,	Min.,	2	87.5	6.4	2.1	.2	3.4	.7	110
	Max.,	2	93.6	12.5	2.7	.5	7.2	2.1	205
	Avg.,	2	**90.5**	**9.5**	**2.4**	**.4**	**5.3**	**1.4**	**155**
Cabbage, inner leaves,*	Min.,	2	91.9	5.7	1.5	.2	3.4	.6	100
	Max.,	2	94.3	8.1	1.5	.2	5.7	.6	140
	Avg.,	2	**93.1**	**6.9**	**1.5**	**.2**	**4.6**	**.6**	**120**
Cauliflower,		1	90.8	9.2	1.6	.8	5.0	.8	155
Lettuce,	Min.,	3	91.5	5.4	1.4	.4	2.4	.9	90
	Max.,	3	94.6	8.5	1.8	.6	4.9	1.2	150
	Avg.,	3	**93.1**	**6.9**	**1.6**	**.5**	**3.7**	**1.1**	**120**
Spinach,		1	92.4	7.6	2.1	.5	3.1	1.9	120
Rhubarb, stems,		1	92.7	7.3	.8	1.2	4.4	.9	145
Asparagus,	Min.,	3	93.6	5.8	1.6	.2	3.1	.5	105
	Max.,	3	94.2	6.4	2.1	.3	3.5	1.0	110
	Avg.,	3	**94.0**	**6.0**	**1.8**	**.2**	**3.3**	**.7**	**105**
Tomatoes,	Min.,	6	95.5	3.7	.7	.3	2.2	.3	75
	Max.,	6	96.3	4.5	.9	.5	2.8	.4	80
	Avg.,	6	**96.0**	**4.0**	**.8**	**.4**	**2.5**	**.3**	**80**
Tomatoes, canned,		1	94.7	5.3	1.0	.2	3.7	.4	95
Green peas,		1	78.1	21.9	4.4	.5	16.1	.9	400
Green peas, canned,		1	82.9	17.1	4.3	.3	11.4	1.1	305
String beans,	Min.,	2	83.5	9.0	1.7	.3	6.3	.7	160
	Max.,	2	91.0	16.5	2.8	.4	12.6	.8	305
	Avg.,	2	**87.2**	**12.8**	**2.2**	**.4**	**9.5**	**.7**	**235**

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* These, as ordinarily found in the market, have more or less refuse. The figures for composition for all of them, except "Cabbage, entire," as for the other vegetable food materials, apply to the edible portion.

TABLE 33.—*(Continued.)*

FOOD MATERIALS.		No. of Analyses.	Water.	NUTRIENTS.					Potential Energy in one Pound.
				Total.	Protein.	Fat.	Carbo-hydrates.	Mineral Matters.	
Vegetable Foods.			%	%	%	%	%	%	Cal.
Lima beans, green,		1	68.5	31.5	7.1	.7	22.0	1.7	570
Okra,		1	87.4	12.6	2.0	.4	9.5	.7	230
Green sweet corn,		1	81.2	18.8	2.8	1.1	14.2	.7	360
Green sweet corn, canned,		1	71.8	28.2	3.0	1.3	22.5	1.4	530
Egg plant,		1	92.9	7.1	1.2	.3	5.1	.5	130
Apples, "flesh,"	Min.,	2	82.2	15.9	.2	.3	15.1	.2	300
	Max.,	2	84.1	17.8	.3	.5	16.7	.3	335
	Avg.,	2	**83.2**	**16.8**	**.3**	**.4**	**15.9**	**.2**	**320**
Peas,		1	83.9	16.1	.6	.8	14.2	.5	290
Cherries, "flesh,"		1	86.1	13.9	1.1	.8	11.4	.6	265
Strawberries,	Min.,	19	87.7	6.0	.6	.4	4.4	.4	120
	Max.,	19	94.0	12.3	1.2	1.1	8.3	.8	235
	Avg.,	19	**90.8**	**9.2**	**1.0**	**.7**	**6.9**	**.6**	**175**
Blackberries,		1	88.9	11.1	.9	2.1	7.5	.6	245
Whortleberries,		1	82.4	17.6	.7	3.0	13.5	.4	390
Cranberries,		1	87.6	12.4	.4	.9	10.9	.2	350
Grapes, Catawba,		1	74.8	25.2	1.6	1.7	21.3	.6	500
Lemons,	Min.,	2	88.4	9.8	.8	.2	8.2	.5	175
	Max.,	2	90.2	11.6	1.1	1.6	8.5	.5	245
	Avg.,	2	**89.3**	**10.7**	**1.0**	**.9**	**8.3**	**.5**	**210**
Oranges,	Min.,	–	—	—	—	—	—	—	—
	Max.,	–	—	—	—	—	—	—	—
	Avg.,	–	—	—	—	—	—	—	—
Banana, pulp,		1	66.3	33.7	1.4	1.4	29.8	1.1	640
Pineapple,		1	89.3	10.7	.4	.3	9.7	.3	200
Water-melon, "flesh" or pulp,		1	91.9	8.1	.9	.7	6.2	.3	160
Nutmeg melon, "flesh" or pulp,		1	76.4	23.6	1.4	.2	20.5	1.5	415
Rice,	Min.,	10	11.4	86.0	.9	.3	77.6	.3	1600
	Max.,	10	14.0	88.6	8.6	.6	81.0	.5	1655
	Avg.,	10	**12.4**	**87.6**	**7.4**	**.4**	**79.4**	**.4**	**1630**
Beans, dried,	Min.,	3	10.4	85.0	20.4	1.4	57.2	2.7	1560
	Max.,	3	15.0	89.6	26.6	3.1	60.4	3.7	1685
	Avg.,	3	**12.6**	**87.4**	**23.1**	**2.0**	**59.2**	**3.1**	**1615**
Maize meal,	Min.,	77	8.0	72.6	7.1	2.0	60.9	.9	1405
	Max.,	77	27.4	92.0	13.9	5.1	77.1	4.1	1805
	Avg.,	77	**15.0**	**85.0**	**9.2**	**3.8**	**70.6**	**1.4**	**1645**
White hominy,	Min.,	2	13.4	86.4	8.1	.4	77.4	.4	1610
	Max.,	2	13.6	86.6	8.4	.5	77.5	.5	1620
	Avg.,	2	**13.5**	**86.5**	**8.3**	**.4**	**77.4**	**.4**	**1620**
Oat meal,	Min.,	6	6.2	91.2	12.9	6.1	67.3	1.8	1820
	Max.,	6	8.8	93.8	16.3	8.8	70.1	2.2	1875
	Avg.,	6	**7.8**	**92.2**	**14.7**	**7.1**	**68.4**	**2.0**	**1845**
Pearl barley,		1	11.8	88.2	8.4	.7	78.1	1.0	1635
Rye flour,	Min.,	4	12.4	86.4	.6	.8	77.9	.6	1615
	Max.,	4	13.6	87.6	7.1	.9	79.5	.8	1625
	Avg.,	4	**13.1**	**86.9**	**6.7**	**.8**	**78.7**	**.7**	**1625**

TABLE 33.—*(Continued.)*

FOOD MATERIALS.		No. of Analyses.	Water.	NUTRIENTS.					Potential Energy in one Pound.
				Total.	Protein.	Fat.	Carbo-hydrates.	Mineral Matters.	
Vegetable Foods.			%	%	%	%	%	%	Cal.
Wheat flour, - -	Min.,	22	8.2	85.7	8.6	.6	71.6	.3	1625
	Max.,	22	14.3	91.8	13.6	1.8	79.5	.7	1680
	Avg.,	22	**12.5**	**87.5**	**11.0**	**1.1**	**74.9**	**.5**	**1645**
Graham flour, - -	Min.,	3	12.1	86.3	11.3	1.5	71.6	1.7	1610
	Max.,	3	13.7	87.9	12.4	1.9	72.0	2.0	1645
	Avg.,	3	**13.1**	**86.9**	**11.7**	**1.7**	**71.7**	**1.8**	**1625**
Entire wheat flour, -	Min.,	2	12.9	86.9	13.1	1.9	69.5	1.4	1615
	Max.,	2	13.1	87.1	14.1	2.0	70.5	1.4	1660
	Avg.,	2	**13.0**	**87.0**	**13.6**	**2.0**	**70.0**	**1.4**	**1640**
Cracked wheat, -	Min.,	2	9.8	88.9	11.9	1.5	73.9	1.4	1660
	Max.,	2	11.1	90.2	12.0	1.8	75.2	1.4	1700
	Avg.,	2	**10.4**	**89.6**	**11.9**	**1.7**	**74.6**	**1.4**	**1680**
Buckwheat flour, -	Min.,	4	12.8	82.4	4.2	.7	71.6	.7	1560
	Max.,	4	17.6	87.2	8.1	1.8	79.6	1.3	1640
	Avg.,	4	**14.6**	**85.4**	**6.9**	**1.4**	**76.1**	**1.0**	**1605**
Buckwheat farina, - - -		1	11.2	88.8	3.3	.3	84.8	.4	1650
Buckwheat groats, - - -		1	10.6	89.4	4.8	.6	83.4	.6	1665
Wheat bread, - -	Min.,	5	31.2	66.5	8.6	.6	55.2	.6	1245
	Max.,	5	33.5	68.8	9.2	2.5	58.5	1.2	1300
	Avg.,	5	**32.3**	**67.7**	**8.8**	**1.7**	**56.3**	**.9**	**1280**
Graham bread, - - - -		1	34.2	65.8	9.5	1.4	53.3	1.6	1225
Rye bread, - - - -		1	30.0	70.0	8.4	.5	59.7	1.4	1285
Boston crackers, - - -		1	8.3	91.7	10.7	9.9	68.7	2.4	1895
Soda crackers, - - - -		1	8.0	92.0	10.3	9.4	70.5	1.8	1900
Pilot (bread) crackers, - -		1	7.9	92.1	12.4	4.4	74.2	1.1	1795
Oyster crackers, - - -		1	3.9	96.1	11.3	4.8	77.5	2.5	1855
Oat meal crackers, - - -		1	4.9	95.1	10.4	13.7	69.6	1.4	2065
Graham crackers, - - -		1	5.0	95.0	9.8	13.6	69.7	1.9	2050
Starch, - - - - - -		2	2.0	98.0	—	—	97.8	.2	1820
Sugar, granulated, - - -		–	2.0	98.0	—	—	97.8	.2	1820
Molasses, - - - - -		–	24.6	75.4	—	—	73.1	2.3	1360

COMPOSITION OF ORDINARY FOOD MATERIALS.

The number of analyses of materials used for the food of man in the United States is not yet sufficient for compiling satisfactory tables of average composition. To make such tables as are needed, it will be necessary to have, not hundreds of analyses merely, but thousands, in order to show the range of variation and the average for each of a very large number of materials. At the same time the analyses at hand will serve for the construction of tables that may be used tentatively. An attempt in this direction has been made in the tables herewith. But we wish to insist that they represent only our present information, which is very imperfect, and are subject to revision as new material accumulates.

Tables 32 and 33 (pages 75–88) summarize the results of the American analyses of meats, fish, and other animal foods that have come to our notice. Table 32 gives the percentages for the materials in the condition in which they are purchased in the markets, including both refuse and edible portion. Table 33 shows the composition of the total edible portion, including water, but excluding the refuse in the inedible portion. This table (33) also contains the results of American analyses of vegetable materials used as food for man. The most of these latter are taken from a compilation of feeding stuffs made for the Office of Experiment Stations by Dr. E. H. Jenkins. The figures for the composition of vegetable foods "as purchased," including both edible portion and refuse, are not given with those of animal foods in table 32, because so many have no refuse, and the data at hand do not suffice for estimates of refuse in those in which, like potatoes, turnips, cabbage, etc., the quantity is large enough to take into account. For like reasons the analyses of milk, cheese, butter, and oleomargarine, which contain no refuse, are not given in table 32.

With regard to the figures assumed for the composition of dairy products, it should be stated that they are based upon such data as we had conveniently at hand, without attempting to collate all the American analyses that have been made, and which, especially in the case of milk, are very considerable. For the other food materials in the table, we believe that the figures represent very nearly all the reliable analyses thus far reported, as Dr. Jenkins' compilation of analyses of vegetable materials is exhaustive up to the time when it closed, and we have been able to find practically none of meats, fowl, and fish, outside of those made in this laboratory.

But a few words of explanation of the tables are needed here. "Maximum" and "minimum" represent in each case the largest and the smallest percentage of each ingredient found in any specimen of the material named. Hence, they do not show the composition of any one specimen, but rather the extreme percentages of each ingredient determined in the different specimens analyzed. Of course, they do not foot up to 100 per cent., but those for minimum fall below, and those for the maximum rise above

100. These figures are given in order to indicate, so far as the data will allow, the variations in composition that may be expected in these materials. The variations in the composition of the same cut of meat from different animals, and the differences noted in the analyses of different specimens of fish, are very wide. It is evident that for most of the materials, and especially for the meats and the fatter kinds of fish, the averages in these tables must be taken as only approximate representations of the composition of the food products as we buy and use them. The last column of each table gives the Calories of potential energy in one pound of the food material. The reason for introducing this factor, and the way in which the calculations are made, are explained in the Report of the Station for 1890, pages 174–181.

A STUDY OF DIETARIES.

BY CHAS. D. WOODS.

Two dietaries have been studied during the year, and are reported in detail herewith. The general plan followed in these studies is the same as was used in the earlier work by Prof. Atwater,* though more detailed and thorough methods have been employed.

DIETARY OF A BOARDING-HOUSE.

In connection with the United States Department of Labor, a study was made of the dietary of a boarding-house in Middletown, Conn. The details of the investigation were carefully carried out by Mr. H. B. Gibson, at that time Assistant Chemist to the Station. Mr. G. Gehring shared in the work of analysis. During the whole period of the investigation, Mr. Gibson boarded at the house and kept account of everything purchased and of kitchen and table wastes. To the accurate execution of the details by him much of the success of the investigation is due.

The general plan of the investigation included account of all food materials of nutritive value in the house at the beginning, that purchased during and that which remained at the end of the experiment. In addition to this, all the kitchen and table wastes of the food were collected, taken to the laboratory and there weighed and analyzed. The amount of different food materials on hand at the beginning and received during the experiment were added; from this sum the amounts remaining at the end were subtracted. This gave the amount of each material actually used. From the amounts thus obtained and the composition of each material as shown by analysis, the amounts of the nutritive ingredients were estimated. From this were subtracted the amounts of nutrients in the waste, and thus the amounts of nutrients in the food actually eaten were learned.

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* See chapter on American and European Dietaries and Dietary Standards.

Duration of the Experiment.—The dietary commenced with supper, October 20th, 1890, and continued until after dinner of November 19th, a period of thirty days.

Members of the Family and Meals Eaten.—During most of the time the family consisted of thirteen men and seven women. It very rarely happened that all of the family took all three meals at the house any given day. There were occasional visitors, and in this way once or twice the total number of meals taken per day was larger than the family alone would have required. The sex, approximate age and occupation of each member of the family, as it was constituted most of the time, were as follows :

Men—4 Machinists, 30–40 years of age.
1 Machinist, about 35, after Oct. 25th.
1 Harness maker, about 70.
2 Hired men about the stable, one old, the other middle aged.
1 Proprietor of the house, about 70.
2 Manufacturers, one about 60, the other about 30.
1 Chemist, about 27.
1 Reporter for newspaper, about 20, after Oct. 27th.
—
13

Women—1 Housekeeper, about 30.
1 Cook, about 45.
1 Table girl, about 20.
4 Doing no manual labor, about 30, 55, 55 and 70.
1 Young lady at house four days, doing no labor.
—
8

Of the thirteen men, three were counted as "hearty eaters," and six more as having decidedly good appetites.

An account of the number of meals taken each day was kept, and is given in the following table:

Number of Meals Taken at the House Each Day.

Oct.	Men.	Women.	Nov.	Men.	Women.	Nov.	Men.	Women.
20	10	7	1	42	18	13	38	14
21	32	21	2	40	16	14	37	16
22	29	23	3	40	16	15	38	16
23	32	25	4	36	16	16	37	18
24	32	23	5	39	18	17	37	18
25	30	17	6	38	19	18	37	19
26	25	21	7	36	18	19	21	11
27	34	19	8	37	16			
28	35	19	9	33	14	Total,	1060	536
29	35	18	10	33	13			
30	34	18	11	38	13			
31	37	20	12	38	16			

The actual number of meals taken at the house during the thirty days of the experiment was 1,596, of which 1,060 were eaten by men and 536 by women. Assuming, in accordance with the dietary standards given in the succeeding chapter that on the average one woman ate eight-tenths as much as one man, this would reduce the whole number of meals to an equivalent of 1,489 for the 30 days, or three meals per day for 496 days for one man.

Food Used During the Experiment.—The actual amount of food and of nutrients in the food used during the dietary is shown in table 34, which follows. The weights of the food materials are as they were purchased and used; that is, they include bone and other refuse except where specified.

The first three columns in the table contain the percentages of protein, fat and carbohydrates used in computing the amounts of these nutrients in the different food materials.

In nearly all cases analyses were made of specimens of the food materials actually used in the dietary, or of specimens so nearly identical with those used that they might properly serve for the analysis. The analysis was omitted in a few cases, but only where previous analyses were thought to furnish reasonably accurate data for estimates of the composition.

TABLE 34.

Food Materials Used in Dietary of Boarding-House for 13 Men and 8 Women during 30 Days.

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
					Nutrients.		
	Protein.	Fat.	Carbohydrates.	Total Food Materials.	Protein.	Fat.	Carbohydrates.
ANIMAL FOODS.	%	%	%	Grams.*	Grams.	Grams.	Grams.
Beef.							
Short steak,	18.6	19.2	—	5,780	1,075	1,109	—
From soup bones,	16.8	30.3	—	1,100	185	333	—
Chuck ribs,	13.2	19.7	—	18,270	2,412	3,599	—
Chuck ribs,	15.2	28.7	—	3,290	500	944	—
Chuck ribs,	16.3	13.3	—	2.720	443	362	—
Chuck ribs,	15.6	17.8	—	2,780	434	495	—
Shoulder,	17.3	8.8	—	2,610	452	230	—
Roast, free from bone,	17.1	19.9	—	2,780	475	552	—
Roast, free from bone,	16.1	32.9	—	2.500	403	823	—
Roast, free from bone,	16.0	32.0	—	2,160	346	691	—
Roast, free from bone,	16.8	30.3	—	2,670	449	809	—
Roast, free from bone,	15.2	36.6	—	2,720	413	996	—
Suet,	.9	94.6	—	340	3	322	—
Corned,	13.2	21.3	—	14,050	1,855	2,993	—
Corned,	11.7	37.2	—	9.370	1,096	3,485	—
Corned, canned,	24.5	20.2	—	11,168	2,736	2,256	—
Dried,	29.9	4.5	—	3,400	1,017	1,153	—
Tripe,	13.5	1.9	—	2,950	398	56	—
Bologna sausage,	18.8	15.8	—	3,970	746	627	—
Total,	—	—	—	94,628	15,438	21,835	—
Veal.							
Shoulder,	18.3	5.5	—	9,750	1,784	536	—
Miscellaneous cuts,	14.9	10.2	—	3,400	507	347	—
Total,	—	—	—	13,150	2,291	883	—
Pork.							
Ribs,	13.5	25.4	—	3,400	459	864	—
Ribs and shoulder,	14.1	25.6	—	6,410	904	1,641	—
Shoulder,	13.8	28.9	—	1,470	203	425	—
Chops,	13.2	31.9	—	8,560	1,130	2,731	—
Salt, fat,	.9	82.8	—	1,250	113	1,035	—
Ham, smoked,	14.8	34.6	—	22,340	3,306	7,730	—
Sausage,	11.2	45.4	—	8,280	928	3,759	—
Lard,	—	90.0	—	6,350	—	5,715	—
Total,	—	—	—	58,060	7,043	23,900	—
Lamb.							
Ribs,	16.7	22.1	—	4,650	777	1,028	—
Shoulder,	13.5	22.8	—	11,790	1,592	4,280	—
Leg,	15.6	12.6	—	6,340	989	789	—
Total,	—	—	—	22,780	3,358	6,097	—
Fowl and chicken,	15.1	1.2	—	14,290	2,158	171	—

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 34.—*(Continued.)*

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo-hydrates.	Total Food Materials.	Nutrients. Protein.	Nutrients. Fat.	Nutrients. Carbo-hydrates.
Fish.	%	%	%	Grams.*	Grams.	Grams.	Grams.
Flounder, dressed, -	6.3	.3	—	4,200	265	13	—
Haddock, dressed, -	9.9	.2	—	6,860	679	14	—
Cod, salt, - - -	16.0	.4	—	790	126	3	—
Round clams, shell cont'nts,	6.5	.4	—	3,910	254	16	—
Total, - - -	—	—	—	15,760	1,324	46	—
Dairy Products, Etc.							
Butter, - - - -	—	80.0	—	34,190	—	27,352	—
Milk, - - - -	3.5	4.5	4.9	191,400	6,699	8,613	9,379
Cheese, - - - -	27.1	35.5	2.3	1,130	306	401	26
Total, - - -	—	—	—	226,720	7,005	36,366	9,405
Eggs, - - - -	12.2	10.2	—	12,560	1,532	1,281	—
Total animal foods, -	—	—	—	457,948	40,149	90,579	9,405
VEGETABLE FOODS.							
Onions (10 % refuse), -	1.4	.3	10.1	6,120	86	18	618
Sweet potatoes, (12.5 % refuse), - - -	1.5	.4	26.0	30,564	458	122	7,947
Potatoes (15 % refuse), -	2.1	.1	17.9	98,175	2,062	98	17,573
Squash (50 % refuse), -	.9	.2	10.1	3,400	31	7	343
Cabbage (15.5 % refuse),	1.5	.2	5.7	14,895	223	30	849
Turnips (30 % refuse), -	1.2	.2	8.2	38,150	458	76	3,128
Canned corn, - -	3.0	1.3	22.5	3,870	116	50	871
Canned peas, - -	4.3	.3	11.4	3,945	170	12	449
Canned tomatoes, - -	1.0	.2	3.7	5,190	52	10	192
Dried beans, - - -	22.2	1.4	60.3	4,080	906	57	2,460
Apples (25 % refuse), -	.3	.4	15.9	33,875	102	136	5,385
Cranberries, - - -	.4	.9	10.9	2,640	11	24	288
Grapes (25 % refuse), -	1.7	1.7	21.3	10,120	172	172	2,156
Flour, - - - -	13.5	1.3	74.0	124,500	16,908	1,619	92,130
Buckwheat flour, - -	6.9	1.4	76.1	1,810	125	25	1,377
Corn starch, tapioca, and pearl barley, - -	—	—	97.5	1,130	—	—	1,102
Hominy, - - -	8.2	.4	77.4	2,270	186	9	1,757
Oat meal, - - -	15.1	7.1	68.2	1,470	222	104	1,002
Crackers, - - -	10.7	9.9	68.8	1,360	146	135	936
Sugar (water-free), -	—	—	100.0	60,780	—	—	60,780
Molasses and syrup (63 % sugar), - - -	—	—	63.0	6,630	—	—	418
Total, - - -	—	—	—	454,974	22,434	2,704	201,761
Total animal and vegetable foods, - -	—	—	—	912,922	62,583	92,262	211,166

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

The data of table 34 are summarized in table 35, in which the weights are stated in pounds as well as in grams. As before explained, it was estimated that the food consumption was equivalent to that for one man for a period of 496 days. The table gives the quantities estimated per man per day on this basis. These figures apply to the food as purchased.

TABLE 35.

RECAPITULATION OF DIETARY OF BOARDING-HOUSE.

Weights of Food Materials and of Nutritive Ingredients Used.

KINDS OF FOOD MATERIALS.	WEIGHT IN GRAMS.				WEIGHT IN POUNDS.			
	Food Materials.	Nutrients.			Food Materials.	Nutrients.		
		Protein.	Fats.	Carbo-hydrates.		Protein.	Fats.	Carbo-hydrates.
For 21 Persons, 30 Days.	Grams.	Grams.	Grams.	Grams.	Lbs.	Lbs.	Lbs.	Lbs.
Meats, etc., - -	202,908	30,288	52,886	—	446	67	116	—
Fish, - - - -	15,760	1,324	46	—	35	3	—	—
Dairy Products, Butter, -	34,190	—	27,352	—	75	—	60	—
Cheese,	1,130	306	401	26	3	1	1	—
Milk, -	191,400	6,699	8,613	9,379	421	15	19	21
Total, -	226,720	7,005	36,366	9,405	499	16	80	21
Eggs, - - -	12,560	1,532	1,281	—	28	3	3	—
Total animal food, -	457,948	40,149	90,579	9,405	1,008	89	199	21
Vegetable food, - -	454,974	22,434	2,704	201,761	1,001	49	6	444
Total food, - -	912,922	62,583	93,283	211,166	2,009	138	205	465
Per Man per Day.								
Meats, etc., - -	409	61.1	106.6	—	.9	—	—	—
Fish, - - - -	32	2.7	.1	—	.1	—	—	—
Dairy Products, Butter, -	69	—	55.2	—	.2	—	—	—
Cheese,	2	.6	.8	—	—	—	—	—
Milk, -	386	13.5	17.4	18.9	.8	—	—	—
Total, -	457	14.1	73.4	18.9	1.0	—	—	—
Eggs, - - -	25	3.1	2.6	—	.1	—	—	—
Total animal food, -	923	81.0	182.7	18.9	2.1	.18	.40	.04
Vegetable food, - -	917	45.2	5.5	406.9	2.0	.10	.01	.90
Total food, - -	1,840	126.2	188.2	425.8	4.1	.28	.41	.94

Table 35 tells its story so plainly as to require little comment. It will, however, be interesting to note the proportion of the several kinds of food materials in the dietary and the relative proportions of the several nutrients furnished by each. These are expressed in percentages in table 36. Thus in the column under "Total Food Materials," it will be observed that the meats make up 22.2 per cent., the milk 21 per cent. and the butter and cheese sufficient to make the total daily products 26.5 per cent.; the animal food altogether 50.1, and the vegetable food 49.0 per cent. of the total food purchased. Of the whole protein, 48.4 per cent. was supplied in the meats, 2.2 per cent. in the fish, and so on.

TABLE 36.

Percentages of Food Materials of Different Classes and of Nutrients furnished by Each Class.

KINDS OF FOOD MATERIALS.		Total Food Materials.	NUTRIENTS.		
			Protein.	Fats.	Carbohydrates.
		%	%	%	%
Meats, etc.,		22.2	48.4	56.7	—
Fish,		1.7	2.2	.1	—
Dairy Products,	Butter,	3.7	—	29.3	—
	Cheese,	.1	.5	.4	.1
	Milk,	21.0	10.7	9.2	4.4
	Total,	24.8	11.2	38.9	4.5
Eggs,		1.4	2.4	9.2	—
Total animal food,		50.1	64.2	97.1	4.5
Vegetable food,		49.9	35.8	2.9	95.5
Total food,		100.0	100.0	100.0	100.0

TABLE AND KITCHEN REFUSE AND WASTE.*

These were made up of bones of meat, parings of potatoes, etc., left in preparing the food for the table, and the scraps of food left on the table uneaten. The percentages of refuse of vegetables and meats were obtained from experiment as described in the foot note. All of the table and kitchen refuse and waste, except parings of vegetables and bones of meat, were carefully collected after each meal and taken to the laboratory. It was there freed from bone and other inedible materials, and then dried for twenty-four hours or more in large evaporating dishes in a water oven at 98° centigrade, as usual in preparing for analysis. While still hot, the fat was removed as far as possible, so as to leave the samples in better condition for grinding. The water-free fat thus removed amounted in all to 2,639 grams. It is accounted for in table 37. The partly dried refuse was allowed to accumulate till five kilograms or more had accumulated, and was then sampled and prepared for analysis. Eight such lots of material were collected and analyzed. The weights of the water-free refuse and its constituents are given in table 37 herewith.

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* See foot note on next page.

TABLE 37.

Percentages and Weights of Nutrients in Table and Kitchen Wastes.

Laboratory No.	Percentage Composition.				Weight of Ingredients.				
					Total Water-free Substance (Nutritive Materials).	Nutrients.			
	Protein.	Fats.	Carbohydrates.	Ash.		Protein.	Fats.	Carbo-hydrates.	Ash.
	%	%	%	%	Grams*	Grams.	Grams.	Grams.	Gr'ms.
307, -	27.44	40.94	28.52	3.10	5,514	1,513	2,258	1,573	170
310, -	26.81	31.57	37.31	4.31	5,772	1,548	1,822	2,154	248
313, -	28.56	38.89	28.84	3.71	4,478	1,279	1,742	1,291	166
317, -	26.50	36.50	32.42	4.58	4,653	1,233	1,698	1,509	213
324, -	28.38	37.39	30.44	3.79	4,831	1,371	1,806	1,471	183
328, -	32.75	40.83	21.45	4.97	5,659	1,853	2,311	1,214	281
334, -	31.31	40.59	23.46	4.64	5,198	1,628	2,110	1,219	241
336, -	25.94	33.27	36.28	4.51	4,215	1,093	1,402	1,529	191
Fat removed, as above explained, -					2,639	—	2,639	—	—
Total grams, - - - -					42,959	11,518	17,788	11,960	1,693
Equivalent to pounds, - -					94.4	25.3	39.1	26.3	3.7

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

NOTE.—The terms "refuse" and "waste" and the ways of determining the amounts demand a word of explanation. The weights given for the food materials in table 34 are those found by weighing them as received, and with few exceptions include both edible portion and refuse. The exceptions are stated in the table, e. g., "Beef roast free from bone." The proportions of refuse in the meats were found by weighing the refuse and edible portion of the specimens analyzed. The percentages of refuse and edible portion thus found are given in the "Tables of Composition of Animal Foods," in the chapter on "Composition of Food Materials." Those figures for refuse accordingly represent actually inedible material and not waste in the proper sense, i. e., valuable material wasted, except in so far as the bone, etc., may be utilized for soup. The figures in table 34 for refuse of the vegetable foods, e. g., parings of potatoes and turnips, stem and outside leaves of cabbage, rind and seeds, etc., of squash, were determined approximately by weighings at the house. They represent not only the actually inedible material, but also more or less of edible material removed with it. For instance, it was estimated from weighings of the parings of the potatoes that out of 100 pounds, 15 pounds were removed in the kitchen, and only 85 pounds served on the table. These 15 pounds were made up in part of the skin and adhering earth, which might be properly called refuse. The rest was edible material which, if it had been saved and served, would have been as wholesome as that which went on the table, and may be appropriately designated as waste. The terms refuse and waste are here used somewhat indiscriminately. Perhaps a correct terminology would make the refuse consist of the actually inedible material and waste, the latter term covering the edible material rejected with the refuse. While the use of terms is unimportant, the subject itself is an important one for American household economy.

Table 38.

Nutrients and Potential Energy in Food Purchased, Rejected and Eaten.

		Nutrients.			Potential Energy.
		Protein.	Fats.	Carbo-hydrates.	
Whole Experiment—21 Persons, 30 Days.		Grams*.	Grams.	Grams.	Calories.
Food purchased,	Animal, - -	40,149	90,579	9,405	1,045,560
	Vegetable, - -	22,434	2,704	201,761	944,350
	Total, - - -	62,583	93,283	211,166	1,989,910
Waste, - -	Animal, - -	10,190	17,621	—	205,650
	Vegetable, - -	1,328	167	11,960	56,030
	Total, - - -	11,518	17,788	11,960	261,680
Food actually eaten,	Animal, - -	29,959	72,958	9,405	839,900
	Vegetable, - -	21,106	2,537	189,801	888,310
	Total, - - -	51,065	75,495	199,206	1,728,210
Per Man per Day.					
Food purchased,	Animal, - -	81.0	182.7	18.9	2,110
	Vegetable, - -	45.2	5.5	406.9	1,900
	Total, - - -	126.2	188.2	425.8	4,010
Waste, - -	Animal, - -	20.5	35.5	—	410
	Vegetable, - -	2.7	.3	24.1	110
	Total, - - -	23.2	35.8	24.1	520
Food actually eaten,	Animal, - -	60.4	147.1	18.9	1,690
	Vegetable, - -	42.6	5.1	382.8	1,790
	Total, - - -	103.0	152.2	401.7	3,480
Percentages of Total Food Purchased.		%	%	%	%
Food purchased,	Animal, - -	64.2	97.1	4.5	52.5
	Vegetable, - -	35.8	2.9	95.5	47.5
	Total, - - -	100.0	100.0	100.0	100.0
Waste, - -	Animal, - -	16.3	18.9	—	10.0
	Vegetable, - -	2.1	.2	5.6	2.7
	Total, - - -	18.4	19.1	5.6	12.7
Food actually eaten,	Animal, - -	47.9	78.2	4.5	41.2
	Vegetable, - -	33.7	2.7	89.9	43.7
	Total, - - -	81.6	80.9	94.4	84.9

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

It will be worth while to estimate, as well as may be, how much of the nutritive material wasted came from the animal, and how much from the vegetable food. As there were practically no carbohydrates in any of the animal food materials except milk and cheese, and but little in these, we shall not greatly err in assuming that all the waste carbohydrates came from the vegetable foods. For a rough calculation, it will also be safe to assume that the proportions of protein and fat in the vegetable portion of the waste were the same as in the whole vegetable food. In the latter the weight of the protein is 11.1 per cent., and that of fat 1.4 per cent. of the weight of the carbohydrates. Taking the same percentages of the weight of the carbohydrates in the total waste as the measure of the protein and fats in the vegetable waste, we have the actual weights of protein and fats in the latter. Subtracting these weights of vegetable protein and fat from the total weights of these ingredients in the waste, we have as the remainder, the amounts of animal protein and fat in the whole waste.

The proportions of nutritive ingredients in the food purchased, in the waste and in the food actually consumed are given in table 38, on the preceding page. The estimates of animal and vegetable nutrients in the waste are computed as above described, and those of potential energy (fuel-value of nutritive ingredients) as explained in the chapter beyond.

About one-ninth of the total nutritive ingredients of the food was left in the kitchen and table wastes. The actual waste was worse than this proportion would imply, because it consisted mostly of the protein and fats which are more costly than the carbohydrates. The waste contained nearly one-fifth of the total protein and fat, and only one-twentieth of the total carbohydrates of the food. Or, to put it in another way, the food purchased contained about 23 per cent. more protein, 24 per cent. more fats, and 6 per cent. more carbohydrates than were eaten. And, worst of all, for the pecuniary economy or lack of economy, the wasted protein and fats were mostly from the meats which supply them in the costliest form. At the ratio in which the nutrients were actually eaten in this dietary, the protein in the waste would have sufficed one man for 112 days; the fats would have supplied him also for 112 days, and the carbohydrates for 30 days.

DIETARY OF FAMILY OF A CHEMIST, MIDDLETOWN.

During the month of April, 1891, the food actually eaten in the family of a chemist in Middletown was carefully weighed, and while no analysis was made of the food or of the table waste, it is believed that the figures given below are quite reliable.

The food materials used were mostly of such a nature that their composition is fairly well known from the averages of other analyses. The waste was reduced to a minimum, and it is probably fair to assume that no very considerable error was introduced by neglecting it. As both of the Station chemists lived in the family and the wife of one of them was very much interested in the experiment, a very careful account of the weights of food used was kept. For the most part the food was weighed just before using, on a scale sensitive to 1 gram with a charge of 10 kilograms.

The Family was as follows :—Chemist, 34 years old, weighing 230 pounds, with moderate exercise, a hearty eater. At home equivalent to 27 days.

Wife of above, 33 years old, weighing 135 pounds. Good appetite. At home the whole 30 days.

Chemist, 27 years old, weighing 175 pounds. Hearty eater, moderate exercise. At home equivalent to 16 days.

Maid servant, about 20, weighing about 120 pounds. Good appetite. At home equivalent to 28⅓ days.

Lady visitor about 60, weight about 100 pounds. Very little exercise and not very hearty eater. At the house equivalent to 10 days.

One other visitor, a man, was at the house equivalent to ⅔ of one day.

This gave equivalent to 43⅔ days for one man, and 68⅓ days for one woman. Supposing, as in the previous dietary, a woman to eat eight-tenths as much as a man, the total dietary would be equivalent to that of one man for 98⅓ days.

Table 39, which follows, gives the percentage composition, the weight of food as eaten, and the calculated nutrients therein. In tables 40 and 41 the statistics are summarized, as was done in the account of the previous dietary, except that, as the quantity of waste was so small, it was not taken into account.

TABLE 39.

Percentage Composition, and Weights of Nutrients in Dietary of a Chemist's Family.

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
					NUTRIENTS.		
	Protein.	Fat.	Carbohydrates.	Total Food Materials.	Protein.	Fat.	Carbohydrates.
ANIMAL FOOD.	%	%	%	Grams*	Grams	Grams	Grams
Beef.							
Lean, cooked, - -	26.7	17.1	—	1,705	455	292	—
Lean, corned, no bone, round, - - -	20.5	10.1	—	2,740	562	277	—
Lean, no bone, - -	20.5	10.1	—	1,960	402	198	—
Sirloin, - - - -	15.0	16.4	—	2,215	332	363	—
Liver, - - - -	20.1	5.4	3.5	2,335	469	126	82
Dried Beef, - - -	28.8	4.4	1.4	225	65	10	3
Veal, - - - - -	16.6	7.9	—	6,775	1,125	535	—
Ham, - - - - -	14.8	34.6	—	2,700	400	934	—
Bacon and Salt Pork, -	.9	82.8	—	935	8	773	—
Lard, - - - -	—	95.0	—	625	—	594	—
Total, - - -				22,215	3,818	4,102	85
Cod, no refuse, - -	15.8	0.4	—	660	104	3	—
Halibut, - - -	15.1	4.4	—	900	136	40	—
Shad, - - - - -	9.2	4.8	—	2,220	204	107	—
Shad, roe, - - -	20.9	3.8	—	210	44	8	—
Striped bass, - - -	8.7	2.2	—	880	77	19	—
Lobster, - - -	13.6	2.0	—	260	35	5	—
Total, - - -				5,130	600	182	
Butter, - - - - -	—	85.0	—	1,810	—	1,540	—
Butter fat, - - -	—	100.0	—	485	—	485	—
Cheese, - - - -	28.3	35.5	1.8	720	204	256	13
Milk, - - - - -	3.6	4.0	4.7	54,000	1,944	2,160	2,538
Total, - - -				57,015	2,148	4,441	25,51
Eggs, - - - - -	12.1	10.2	—	5,140	622	524	—
Total animal food, -				89,500	7,188	9,249	2,636

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* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 39.—*(Continued.)*

FOOD MATRIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
					NUTRIENTS.		
	Protein.	Fat.	Carbohydrates.	Total Food Materials.	Protein.	Fat.	Carbohydrates.
VEGETABLE FOOD.	%	%	%	Grams*	Grams	Grams	Grams
Crackers, etc.,	10.5	9.7	69.6	2,325	244	226	1,618
Macaroni,	9.0	0.3	76.8	565	51	2	435
Entire wheat flour,	11.7	1.7	71.7	14,655	1,715	249	10,508
Wheat flour,	11.0	1.1	74.9	5,625	619	62	4,213
Rye flour,	6.7	0.8	78.7	830	56	7	653
Maize meal, hominy and samp,	9.2	3.8	70.6	1,840	169	70	1,299
Buckwheat flour,	6.9	1.4	76.1	1,000	69	14	761
Oat meal,	15.1	7.1	68.2	210	32	15	143
Sugar (molasses syrup),	—	—	97.8	11,163	—	—	10,917
Tapioca,	—	—	97.8	150	—	—	147
Beans,	20.4	1.6	56.8	3,770	769	60	2,141
Split peas,	26.7	1.7	56.4	100	27	2	56
Rice,	7.4	0.4	79.4	1,540	114	6	1,278
Potatoes,	2.1	0.1	17.9	18,360	386	18	3,286
Cabbage,	2.1	0.3	5.5	1,430	30	4	79
Parsnips,	1.3	0.7	16.2	1,380	18	10	224
Tomatoes (2 cans),	1.0	0.2	3.6	2,075	21	4	75
Corn (1 can),	3.0	1.3	22.5	645	19	8	145
Sweet potatoes,	1.5	0.4	26.0	5,500	83	22	1,430
Dried cocoanut,	8.9	67.0	16.5	70	6	47	12
Raisins,	2.4	0.6	62.0	290	7	2	180
Total,				73,523	4,435	828	39,600
Total food,				163,023	11,623	10,077	42,236

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 40.

Recapitulation of Dietary of a Chemist's Family, Weights of Food Materials, and Nutritive Ingredients.

KINDS OF FOOD MATERIALS.		WEIGHTS IN GRAMS.				WEIGHTS IN POUNDS.			
		Food Materials.	NUTRIENTS.			Food Materials.	NUTRIENTS.		
			Protein.	Fats.	Carbohydrates.		Protein.	Fats.	Carbohydrates.
For Family, 30 Days.		Grams.	Grams	Grams	Grams	Lbs.	Lbs.	Lbs.	Lbs.
Meats, etc., - - -		22,215	3,818	4,102	85	49	8	9	—
Fish, - - - -		5,130	600	182	—	11	1	—	—
Dairy products,	Butter, -	2,295	—	2,025	—	5	—	4	—
	Cheese, -	720	204	256	13	2	—	1	—
	Milk, - -	54,000	1,944	2,160	2,538	119	4	5	6
	Total, -	57,015	2,148	4,441	2,551	126	4	10	6
Eggs, - - - -		5,140	622	524	—	11	1	1	—
Total animal food, -		89,500	7,188	9,249	2,636	197	16	20	6
Vegetable food, - -		73,523	4,435	828	39,600	162	10	2	87
Total food, - - -		163,023	11,623	10,077	42,236	359	26	22	93
Per man per day.									
Meats, etc., - - -		226	39	42	1	.5	.09	.09	—
Fish, - - - -		52	6	2	—	.1	.01	—	—
Dairy products,	Butter, -	23	—	21	—	.1	—	.05	—
	Cheese, -	7	2	3	—	—	—	.01	—
	Milk, - -	550	20	22	26	1.2	.04	.05	.06
	Total, -	580	22	46	26	1.3	.04	.11	.06
Eggs, - - - -		52	6	5	—	.1	.01	.01	—
Total animal food, -		910	73	95	27	2.0	.15	.21	.06
Vegetable food, - -		748	45	8	403	1.6	.10	.02	.89
Total food, - - -		1,658	118	103	430	3.6	.25	.23	.95

TABLE 41.

DIETARY OF A CHEMIST'S FAMILY.

Percentages of Food Materials of Different Classes and of Nutrients Furnished by Each.

KINDS OF FOOD MATERIALS.	Food Materials.	NUTRIENTS.		
		Protein.	Fats.	Carbohydrates.
	%	%	%	%
Meats, etc.,	13.6	32.8	40.7	.2
Fish,	3.2	5.2	1.8	——
Dairy products, Butter,	1.4	——	20.1	——
Dairy products, Cheese,	.4	1.8	2.6	——
Dairy products, Milk,	33.1	16.7	21.4	6.0
Dairy products, Total,	34.9	18.5	44.1	6.0
Eggs,	3.2	5.4	5.2	——
Total animal food,	54.9	61.9	91.8	6.2
Vegetable food,	45.1	38.1	8.2	93.8
Total food,	100.0	100.0	100.0	100.0

It will be interesting to compare the quantities of nutrients and potential energy in the food as purchased, rejected, and actually eaten in the two dietaries herewith reported with those called for in dietary standards. This is concisely done in table 42. The dietary standards are explained in the chapter on American and European dietaries and dietary standards beyond.

TABLE 42.

Comparison of Dietaries here stated with Dietary Standards.

	NUTRIENTS.			Potential Energy.
	Protein.	Fats.	Carbo-hydrates.	
Dietary of a Boarding-house.	Grams	Grams	Grams	Calories.
Food per man per day, Total purchased,	126	188	426	4,010
Food per man per day, Waste,	23	36	25	520
Food per man per day, Actually eaten,	103	152	401	3,490
Dietary of a Chemist's Family.	118	103	430	3,205
Dietary standards for man at moderate manual labor, German, Voit,	118	56	500	3,055
Dietary standards for man at moderate manual labor, American, Atwater,	125	125	450	3,520

SUGGESTIONS REGARDING HOME STUDY OF DIETARIES.

In the succeeding chapter there are given dietary studies which have been proposed for different classes of different people under different circumstances. These are given as illustrations of about the proper quantities of food that such people would need. They are not exact, and even with the most extended observation could only represent averages. Individual peculiarities and demands would always vary somewhat from these standards.

In the case of our domestic animals where, as a result of feeding experiments, standard dietaries have been suggested, it is comparatively easy, since we use but very few kinds of feed, to conform very closely to the standard. With the food of man it is quite a different matter. It is, of course, easy to devise a simple ration which should give exactly what the different standards call for, but in practice this is not feasible, since we use so many kinds of foods. For example, the American standard for a man at moderate work calls for 125 grams (.276 lbs.) of protein, 125 grams (.276 lbs.) of fat, and 450 grams (.992 lbs.) of carbohydrates per day. This would be approximately furnished by ten ounces of lean beef (free from bone), twenty ounces of bread, twenty-five ounces of potatoes, and four ounces of butter, but such a simple ration as this would not serve for ordinary purposes.

While it may be impracticable to bring our daily ration to accord very closely with a standard dietary, it is practicable to see if, in our eating, we are varying very greatly from this standard. If the kinds and amounts of food eaten during a given period, as a week or a month, be recorded, from this data it will be quite easy to calculate the pounds or grams of protein, fats, and carbohydrates that have been used, and in this way we can learn how our actual dietaries vary from what they should be. Thus, in the dietary of a chemist's family (page 104), exactly this method was taken. Careful account was kept of all the food used for a period of thirty days. That this dietary came below rather than above the standard, is perhaps in part to be accounted for from the fact that the persons interested had been making a study of food materials and of the ways in which they should be used for several years.

To persons who are interested in seeing how near their dietaries conform to a standard, the above plan of keeping accurate record of the kinds and amounts of food eaten is recommended.

It is far simpler and less of an undertaking than would at first appear. The only apparatus needed is a reasonably accurate pair of scales.

After the data are collated, it will be easy from the analyses of food materials given in tables 32 and 33, pages 75–88, to calculate the pounds of protein, fats, and carbohydrates that have been used, and if the pounds of protein and the pounds of carbohydrates are multiplied by 1,860, and the pounds of fat by 4,220, and these three products added together, the sum will be the total Calories of energy furnished by the foods eaten.

In general, in such experiments it will be found that the greatest deviation from a standard will be in the case of fats, there being much more used than the standard dietaries call for. This can be partly overcome by greater care in the classes of foods that we purchase, but if we, as most of us do, continue to eat meats two or three times per day, it will be quite difficult to keep the amount of fats from being excessive. It will be noted, however, that fish, especially the white fleshed species, contain very little fat, and that by use of these the amount of protein can be very greatly increased without a corresponding increase in fat.

AMERICAN AND EUROPEAN DIETARIES AND DIETARY STANDARDS.

BY W. O. ATWATER.

In connection with the Massachusetts Bureau of Statistics of Labor, a series of studies of dietaries of factory operatives, mechanics, and other people with moderate incomes, in private families and boarding-houses, were made by the writer in 1886. At the same time, and later, several dietaries of students, laborers and one of a well-to-do private family in Middletown, were examined. Although the work thus done represented only the beginning of an investigation of an important subject, the results warranted generalizations of no little interest, and at the same time served to indicate directions in which further inquiry is needed. The investigation has been renewed in connection with the United States Department of Labor, with results as described by Mr. Woods in the preceding article. The purpose of the present article is to review the work thus far accomplished; present some of the details which have not yet been published; compare the results with those of similar investigations in Europe, where research of this kind has been much cultivated, and state some of the inferences to be drawn regarding diet and dietary standards.

INVESTIGATION OF DIETARIES IN CONNECTION WITH THE MASSACHUSETTS BUREAU OF STATISTICS OF LABOR.

In order to obtain some definite information in regard to the ways of living and especially the food of factory operatives, mechanics, and other working people of native and foreign birth in Massachusetts, the statistics of the amounts and costs of food consumed, and age, sex, and occupation of the consumers, were collected by the Bureau under the direction of its Chief, Hon. Carroll D. Wright, in several manufacturing cities in the State; and as many of the people, whose conditions of life and labor were thus studied, were French Canadians, who come in large numbers to Massachusetts, as to other States bordering upon Canada, and form a not unimportant factor of the population, an agent of the Bureau visited Canada and collated similar statistics regarding the people in the places from which they come. The data thus collated were placed in my hands, and with the assistance of Mr. E. W. Rockwood, then assistant in the chemical laboratory of Wesleyan University, the quantities of nutritive ingredients were estimated, the results of analyses of food materials to those of the dietaries being used as the basis of the calculations. The results were published in detail in an article on "Food Consumption" in the Report of the Bureau for 1886. In the following summary, the more important data are quoted, with so much of the details as will suffice to show the character of the inquiry and bring the results into line with those of later inquiry here. The purpose of the Bureau is thus stated in the report:

> The food problem is one of the most important that can engross the attention of the people. It has a vital connection with the condition of the workingman, and the study of its various branches is essential to a proper understanding of the relative prosperity of industrial periods and the relative status of workingmen in different countries. It also has a directly practical interest for the wage worker, as it is undeniably true that much money is wasted in the purchase of food which is lacking in the elements of nutrition, and that the income of the working classes might be made far more effective if it were expended in accordance with the results of scientific research.

To supply in some measure the information necessary to enable the workingman to more intelligently regulate his expenditures for food, and thus enable him to secure with a given expenditure the maximum amount of nutritive elements, the Bureau has collected a number of schedules of dietaries, giving quantities and costs of food of people, mostly manual laborers, with limited incomes, in Massachusetts and Canada, which have been subjected to chemical analysis in order to estimate the quantities of nutritive material contained in them, and to learn how they compare with regard to nutrients, cost, and fitness for their purpose with each other, as well as with other dietaries, and with recognized standards.

It was not expected that either the data or the time at our disposal would suffice for exhaustive results, but rather that a brief preliminary study might be made which would serve to indicate the methods which should be followed, the sources of error and means for avoiding them, and the results which might be anticipated from a more detailed and complete inquiry, if such should at any time seem desirable and feasible. The results herewith presented are not brought forward as exhaustive therefore, but rather as a preliminary survey of a territory which promises rich rewards if thoroughly explored. While the data are to a certain extent incomplete, the final conclusions, it is believed, are not wide of the truth.

The Dietaries and the People Nourished by Them.—From a larger number collated by the Bureau, thirty, which were regarded as representative, were selected for chemical examinations and the making up of average results. The details of all these are given in the report, and the principal data are summarized in the tables 43 to 47 of "Recapitulations of Analyses of Dietaries" quoted beyond. To save space, however, the figures for only fifteen of the dietaries are given in these tables, though those of the rest are included in the averages in the same tables. The final results of two more, which are not included in the averages for reasons stated, are also given beyond with those of other dietaries. The thirty dietaries summarized in the tables of "Recapitulations" are divided in three series, as follows:

CLASSIFICATION.	Series A. Miscellaneous, Massachusetts.	Series B. French Canadian, Massachusetts.	Series C. French Canadian, Canada.
Data given in tables of recapitulations, - - - -	5	5	5
Data not given, but results included in averages in tables of recapitulations, - -	5*	2*	8
	10	7	13

* Series A included three French Canadian dietaries which are averaged with those of series B, making 10 of the latter, all told, in the averages of series B, and only 7 in the averages for series A in the tables of recapitulations, beyond.

A. Miscellaneous, Massachusetts. These include ten dietaries of families and boarding-houses. The families are nearly all laboring people, while the boarders in the boarding-houses are mostly operatives in mills and factories, though some are clerks, dressmakers, etc. A few are French Canadians.

The five dietaries of this series, of which the data are given in the tables just referred to, include three of boarding-houses and two of families in Lowell, Lynn, East Cambridge, and Boston. Two more of boarding-houses, one in Lowell and one in Lawrence, are included only in the averages, for this series, in the tables. The results for three dietaries of French Canadian families in North Cambridge, of this series, are included in the averages for series B in the tables of recapitulations. The persons are factory and mill operatives, mechanics, etc., with a few clerks and dressmakers.

B. French Canadians, Massachusetts. These include seven dietaries of families and boarding-houses, all of French Canadians. The five dietaries of this series which are used in the tables include those of three families and two boarding-houses in Holyoke, Lawrence, and Lowell. Of those included only in the averages, two were of families in Worcester, of this series, and three of families in East Cambridge, of series A. With the exception of women, children, and others engaged in household duties, or in no actual labor, the people are mostly mill and factory operatives ; a few are brickmakers.

Series A and B are thus divided, as the presence of French Canadian workers in Massachusetts affords an interesting opportunity for comparison, in regard to dietaries, of the same class of workers under the conditions surrounding them in their original habitations and Massachusetts, relatively. This opportunity did not present itself with respect to any other nationality which has selected Massachusetts as its home, and the results of the comparison will in a measure indicate the progress that has been made by the French Canadian since his emigration.

C. French Canadians, Canada. These include dietaries of thirteen families and boarding-houses in Montreal, Quebec, and other places in Canada. The people are represented as all belonging to the laboring classes. The five dietaries of this series which are used in the tables include one of a boarding-house and four of families in Quebec, St. John, Sherbrooke, Richmond, and

Rivière du Loup. The averages include, with these, eight others of families and boarding-houses.

Data. In the descriptions given in the report of the kinds of data employed and the ways in which they were attained, they were classified as follows:

Class A. Those contained in statistics as collected by the agents of the Bureau. They have to do with :

I. Statistics of food materials, including : *a*, kind; *b*, quantity; *c*, costs.

II. Statistics of consumption of food materials, including: *a*, number; *b*, sex; *c*, age; *d*, occupation of persons nourished; and *e*, time.

Class B. Data obtained from other sources and used in the computations. They have to do with:

I. Chemical composition of the food materials. Proportions of nutrients (nutritive ingredients) in each. These figures were employed in computing the quantities of actual nutrients in the dietaries.

II. The proportions of nutrients required by persons differing in age, sex, etc. These proportions were used in estimating the numbers of men at moderate work who would be equivalent in demand for food to the men, women and children nourished by the food for each dietary, the object being to place all the dietaries on a uniform basis for comparison.

In collecting the statistics of Class A, the agents of the bureau visited the houses where the people lived, and the cotton mills, shoe factories, glass factories, machine shops, blacksmith shops, brick yards, and other establishments where they worked, examined the bills of dealers for food furnished, the family and boarding-house accounts, and by these and other appropriate means secured as accurate figures as practicable. To quote from the report:

> The statistics of quantities of food, prices, etc., are compiled from original accounts with tradesmen, and may therefore be relied upon as representing pretty closely the exact facts. The chief source of error is undoubtedly to be found in the fact that the statistics give the amount of food purchased, not that actually eaten. How much was thrown away as refuse or otherwise wasted cannot be ascertained. The housewives and boarding-house keepers would, no doubt, say that this element of waste was extremely small, and generally speaking this is no doubt true from their standpoints. But it is a question whether the actual quantities of wholesome and nutritive material which was left uneaten was not often very much larger than was supposed. Every effort was made to eliminate error throughout the investigation, and it is not probable that the error in the statistics is sufficient to affect materially the averages obtained.

Of the data of Class B, those regarding the composition of the food materials used were estimates rather than the record of actual analysis of the materials which would be required for entire accuracy. For the estimates the results of analyses made in this laboratory, and included with those reported in the chapter on *Composition of Food Materials*, were employed. The other American analyses then available, mostly of dairy and cereal products, were also used. For the few materials of which no American analyses had been made, recourse was had to European figures. The data and methods used in estimating the composition of the food materials are given in detail in the report. The following quotations will give an idea of what they were. The tables referred to are too extensive to be inserted here. The analyses of beef were those described in the chapter on Composition of Food Materials above, as made for the U. S. National Museum.

All our ordinary food-materials vary more or less in composition, and wherever the specimens actually used cannot be analyzed, averages of analyses of other specimens must be used as estimates. For most vegetable foods and dairy products the range of variation is not so wide but that, with the number of analyses at hand, such averages will serve tolerably well. The same may be said of most of our common species of food fishes. But with meats the case is somewhat different, since there are wide variations, not only in the composition of meat from animals of different kinds, but in that from different animals of the same kind and in that from different parts of the same animal.

The method of estimating the composition of beef was as follows:

A large amount, the larger part, we are informed, of the beef consumed in many of our Eastern cities is so-called "Chicago" or "Western" beef, which is slaughtered in Chicago or elsewhere and brought East. From a carload of "Chicago beef" a side was selected by an experienced dealer as of average quality, especial pains being taken to secure one of average fatness. This side of beef was divided into twenty-five pieces, or "cuts," in the manner common in New York markets, and portions of each piece, sufficient to represent the whole, were analyzed, the proportions of refuse (bone, gristle, etc.), water, and nutrients being determined.

A diagram representing these divisions of the beef was placed in the hands of the collectors of the dietaries here examined, who, so far as practicable, indicated in their statements the parts of the animal from which the beef of the several dietaries was taken. The manner of cutting up the beef differs in different places, but not sufficiently to very materially affect the estimates. A more serious matter is the variation of different specimens of beef, and it is, of course, a question how close the side selected for analysis, as above stated, comes to representing the average of the kinds in the dietaries. We are informed that in all the Massachusetts cities, where the dietaries were collected, nearly all the beef used is so-called "Chicago beef," and it is probable that the analyses fairly indicate the quality of the beef sold.

As the best way for utilizing these data, an assistant has gone over the dietaries, noted the "cuts" of beef where stated, and ascribed to each the percentages of nutrients found in the analyses of corresponding "cuts." The results are shown in the following table. Where the original includes two or more "cuts" in one entry, the average is taken. The several computations for "roast beef" are averaged together. The same is done for "beef stew," "beef steak," etc., and some of these latter averages are incorporated in the table beyond, giving the percentages of nutrients in food materials assumed in analyses of dietaries.

The figures used in calculating the amounts of nutrients in the dietaries are generally given in the table showing the percentages of nutrients in food materials assumed in analyses of dietaries. In some special cases, however, they are not given in this table, but are stated with explanations in the explanatory notes appended to the details of the dietaries in which they are used.

To insure perfect accuracy it would, of course, be necessary to analyze the materials actually used in each case. It is probable that while divergences, in some cases very wide, might occur, the figures for the composition of each dietary, as a whole, would be substantially accurate.

The item about which there seems to be the most question is the quantity of fat in the meats, especially the beef. The analyses here used accord very closely with European figures for very fat beef.* Numerous observations, however, which cannot be detailed here, but which seem to be but little short of decisive, imply that the beef commonly used on the continent of Europe is, on the average, less fat than the average beef in our markets. It is certain that much of that commonly used in our Eastern cities is very much fatter than that here analyzed and taken as the basis of these computations.

Attention has been called elsewhere to the fact that the figures for weights of food materials in the dietaries represent the quantities purchased and do not indicate how much was eaten. The rejection of a considerable part of the fat of meats by many persons is one of the most common of dietary facts, at least in the Northern and Eastern States. Some of the fat of beef is left with the butcher, much goes to the soap maker, and much more into the garbage. But a surprisingly large part of the fat of our beef is so diffused through the lean, much of it in invisible particles, that when we have cut out the larger pieces of fat from our roast beef or our steak and left them on our plates, we, nevertheless, eat the bulk of the actual fat of the meat with the lean and the small portions of visible fat which adhere to it.

Especial stress is laid on this point, because the dietaries here studied indicate a remarkably large consumption of fat in this country. The possible bearing of this fact upon our national dietetics may be extremely important.

In the statistics of some of the Massachusetts dietaries, and most of those collected in Canada, the quantities of certain food materials, especially vegetables, were not stated, and had to be estimated from the costs. The uncertainty as to the accuracy of the total estimates was thus increased though, as was believed, not enough, to seriously affect the value of the results for the purpose for which they were intended, namely, an exhibit of the general character of the food consumption and a means toward learning how such an inquiry may be best conducted.

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* See analyses quoted by König, *Nahrungsmittels* Bd. I.

The method for estimating the number of men, at moderate work, who would be equivalent in demands for nutriment to the persons partaking of the food of each dietary, is thus explained in the report:

> Since the people nourished by the dietaries here examined differ in age, sex, and occupation, and hence differ likewise in their demands for nutriment, and since a chief object of the examination is to compare the dietaries with one another in respect to the quantities of actual nutrients supplied, it is clear that to attain our object we need some standard for estimating the relative demands of people of different classes. If, for instance, we could take a particular class, as laboring men at moderate work, and find to how many average men of this class the people nourished by each dietary would be equivalent in their demands for nutrients, we should simply have to divide the total quantity of nutrients supplied per day by this equivalent number of men to get the quantities per man per day. The results thus obtained for the several dietaries would, when compared with each other and with accepted standards, give us what we seek.
>
> We are of the opinion that the experimental data on record in European work, if rightly collated and worked up, would give a basis for at least an approximate estimate of the comparative requirements of the several classes of persons into which those nourished by the food of these dietaries would most properly be divided. Indeed, the current standards for daily dietaries will help in arriving at such a basis. Thus, the standards of Voit and the Munich school of physiologists call for the proportions of nutrients with estimated potential energy, as follows:

PERSONS.	Protein.	Fats.	Carbohydrates.	Potential Energy.
	Grams.	Grams.	Grams.	Calories.
Children to 1½ years old, - -	28	37	75	767
Children, 6 to 15 years old, - -	75	43	325	2,041
Woman at ordinary work, - - -	92	44	400	2,426
Laboring man at moderate work, -	118	56	500	3,055

> We may take the relative quantities of potential energy as the basis of our calculations.
>
> The figures are in about the following relative portions. We interpolate an assumed value for children from 6 to 2 years of age.

Estimated Relative Quantities of Potential Energy in Nutrients Required by Persons of Different Classes.

Laboring man at moderate work, - - - - - -	10
Woman at ordinary work, - - - - - - -	8
Child, 15 to 6 years old, - - - - - - - -	7
Child, 6 to 2 years old, - - - - - - - -	5
Child, under 2 years old, - - - - - - - -	2½

The application of these figures is simple. The food of dietary A, 1, for instance, suffices for 77 persons (factory operatives), 66 males and 11 females. The figures allot to one working woman 0.8 as much nutritive material as to one laboring man at moderate work. This would make the 11 women equivalent to (8.8) 9 men, which added to 66 would make the whole 77 persons equal to 75 men. The 77 persons during 30 days, the time covered by the dietary, would be equal in requirements to one man for 2,250 days. The estimates in the dietaries hereinafter presented are made in this way.

I quote the details of one of the dietaries to show the nature of the statistics collated by the Bureau, and the way in which the quantities of nutrients were estimated. For details of the ways in which the quantities were estimated from the costs in the cases in which they were not given, and for other details, I must refer to the original report, where the details of each of the thirty dietaries are given in full.

TABLE 43.

Dietary Series A, No. 1.

Description.—Boarding-house in Lowell, Mass., of 77 persons, 66 males and 11 females. Boarders, mill operatives. Time, one month. Estimated as equivalent in demands for nutrients to 75 laboring men at moderate work for 30 days, or 1 man for 2,250 days.

ANALYSES.

FOOD MATERIALS.				NUTRIENTS.		
Kinds.	Prices per lb.	Quantities.	Costs.	Prot'in	Fats.	Carbohydrt's.
	Cents.	Lbs.		Lbs.	Lbs.	Lbs.
Beef, roast, - - -	10	400	$40 00	60.4	79.9	—
Beef, steak, - - -	14	272	38 08	39.4	42.4	—
Beef, corned, - - -	7	350	24 50	40.3	99.8	—
Beef tongue, - - -	10	62	6 20	9.2	9.5	—
Beef stew, - - -	5	167	8 35	23.4	52.3	—
Beef, tripe, - - -	6	20	1 20	4.2	0.2	—
Pork, roast, - - -	10	150	15 00	17.1	54.3	—
Ham, - - - -	11	160	17 60	23.4	54.9	—
Salt Pork, - - -	10	70	7 00	2.0	53.6	—
Lard, - - - -	8	260	20 80	—	257.4	—
Haddock, - - - -	7	168	11 76	13.9	0.2	—
Halibut, - - - -	12	50	6 00	7.6	2.1	—
Mackerel, - - - -	3	40	1 20	4.0	1.6	—
Salt fish (cod), - - -	4½	50	2 25	8.0	0.2	—
Total meats, fish, etc., -		2,219	$199 94	252.9	708.4	—
Milk, - - - - -	2	3,024	$60 48	102.8	111.9	145.2
Cheese, - - - - -	11	63.5	6 98	17.2	22.5	1.5
Butter, - - - - -	22 & 10	291	54 54	2.9	254.6	1.5
Eggs, - - - - -	14	107	14 82	12.4	10.9	0.6
Total dairy products and eggs,		3,485.5	$136 82	135.3	399.9	148.8

TABLE 43.—*(Continued.)*

FOOD MATERIALS.				NUTRIENTS.		
Kinds.	Prices per lb.	Quantities.	Costs.	Prot'in	Fats.	Carbohydrt's.
	Cents.	Lbs.		Lbs.	Lbs.	Lbs.
Flour, - - - -	3	1,568	$47 04	174.0	17.2	1,182.3
Sugar, - - - -	7½	600	45 00	—	—	580.2
Molasses, - - - -	4½	99	4 50	—	—	70.3
Beans, - - - -	3	124	3 74	28.8	2.6	66.6
Rice, - - - -	8	25	2 00	1.9	0.1	19.9
Oatmeal, - - - -	4	25	1 00	3.8	1.8	16.8
Potatoes, - - - -	1	2,520	25 20	47.9	5.0	463.7
Squash, - - - -	1½	250	3 75	1.3	0.3	13.3
Onions, - - - -	2	26	50	0.3	—	2.0
Beets, - - - -	5-9	90	50	1.6	0.1	9.0
Turnips, - - - -	5-6	120	1 00	1.1	0.2	6.1
Tomatoes, - - - -	5-6	120	1 00	1.6	0.4	5.4
Apples, - - - -	1⅔	300	5 00	0.9	—	32.7
Raisins, - - - -	12½	24	3 00	0.6	0.1	15.1
Currants, - - - -	10	15	1 50	0.3	—	9.5
Corn Starch, - - -	9	12	1 08	—	—	11.0
Crackers, - - - -	5	48	2 40	5.1	4.8	34.0
Total vegetable food, - -		5,966	$148 21	269.2	32.6	2,537.9
Total animal food, - -		5,704.5	336 76	388.2	1,108.3	148.8
Total food, - - -		11,670.5	$484 97	657.4	1,140.9	2,686.7
Meats, fish, etc., per man per day, - - -	—	.09	$0 99	.11	.31	—
Dairy products and eggs, per man per day, - -	—	1.55	06	.06	.18	.07
Animal food, per man per day, - - - -	—	2.54	$0 15	.17	.49	.07
Vegetable food, per man per day, - - - -	—	2.65	0 07	.12	.01	1.13
Total food, per man per day, - - - -	—	5.19	$0 22	.29	.50	1.20

Results.—The four tables which follow recapitulate the details of fifteen of the dietaries.

Tables 44 and 45 recapitulate the analyses of the dietaries, as estimated per man per day.

Table 46 is sufficiently explained by its title and by the statements made.

Table 47 summarizes in shorter form the principal results set forth in the three preceding.

TABLE 44.

Recapitulation of Statistics of Dietaries. Persons, Employments, Wages, etc., and Quantities and Costs of Food.

Series and Number of Dietary.	PERSONS, EMPLOYMENTS, WAGES, ETC.				FOOD MATERIALS PER MAN PER DAY.										Number of Dietary.
					QUANTITIES.					COSTS.					
	DIETARIES.	OCCUPATION.	Wages per day		Animal food.			Vegetable food.	Total food.	Animal food.			Vegetable food	Total food.	
			Males.	Females.	Meats, fish, etc.	Dairy products and eggs.	Total.			Meats, fish, etc.	Da'y p'd's and eggs.	Total.			
					Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cts.	Cts.	Cts.	Cts.	Cts.	
	Miscellaneous, Mass.														
A 11	Family, E. Cambridge, -	Father, glass-blower,	$4 00[1]	—	.66	.82	1.48	2.97	4.45	9	7	16	9	25	A 11
A 1	Boarding-house, Lowell, -	Mill operatives, -	—	—	.99	1.55	2.54	2.65	5.19	9	6	15	7	22	A 1
A 7	Boarding-house, Lynn, -	Operatives, etc.,[2] -	—	—	.71	.91	1.62	3.48	5.10	10	5	15	9	24	A 7
A 2	Boarding-house, Lowell, -	Mill operatives, -	—	—	.98	1.29	2.27	2.66	4.93	10	5	15	7	22	A 2
A 9	Family, Boston, - -	Husband, machinist,	3 25[3]	—	1.36	1.64	3.00	4.17	7.17	24	12	36	11	47	A 9
	Average of 7 dietaries, -				.88	1.29	2.17	3.02	5.19	11	6	17	8	25	
	French Canadian, Mass.														
B 6	Family, Holyoke, - -	Mill operatives, -	1 35	$0 90	.46	.21	.67	2.35	3.02	7	3	10	7	17	B 6
B 4	Boarding-house, Holyoke[4]	" "	1 25	90	.95	.80	1.75	2.76	4.51	12	6	18	6	24	B 4
B 1	Family, Lawrence, -	" "	—[5]	90	.92	.66	1.58	3.01	4.59	14	4	18	9	27	B 1
B 5	Boarding-house, Holyoke	" "	—[6]	—[7]	1.05	.39	1.44	4.25	5.69	14	5	19	9	28	B 5
B 10	Family, Lowell, - -	Men, blacksmiths,[8]	2 00[9]	1 00	1.28	1.51	2.79	4.40	7.19	18	11	29	10	39	B 10
	Average of 10 dietaries, -				.81	.70	1.51	3.44	4.95	11	5	16	8	24	
	French Canadian, Canada.														
C 18	B'd'g-ho'se, Riv're du Loup	All laboring people,	—	—	.36	.19	.55	1.65	2.20	4	2	6	5	11	C 18
C 12	Family, St. John, - -		—	—	.35	.44	.79	2.02	2.81	3	3	6	5	11	C 12
C 26	Family, Richmond, -		—	—	.63	.45	1.08	2.82	3.90	5	3	8	7	15	C 26
C 24	Family, Sherbrooke, -		—	—	1.13	.55	1.68	2.43	4.11	9	4	13	6	19	C 24
C 6	Family, Quebec, - -		—	—	.57	.98	1.55	2.25	3.80	5	5	10	6	16	C 6
	Average of 13 dietaries, -				.52	.45	.97	2.49	3.46	5	3	8	6	14	

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1. Wages $24.00 per week, work exhausting. 2. Operatives in shoe factory, dressmakers, clerks. 3. $19.50 per week. 4. Board per week, 2.75 for men, $2.00 for women. 5. $1.25 to $1.75 per day. 6. $1.25 to $1.50 per day. 7. 90 cents to $1.00 per day. 8. Woman mill operative. 9. $600 per year.

TABLE 45.

Recapitulation of Statistics of Dietaries. Quantities of Nutrients Estimated per Man per Day.

Series and Number of Dietary.	DIETARIES.	NUTRIENTS SUPPLIED BY DIFFERENT CLASSES OF FOOD MATERIALS.										TOTAL NUTRIENTS SUPPLIED.						Of every 100 parts of protein the different food-materials furnish parts as below.			
		PROTEIN.				FATS.				CARBOHYDRATES.		Hundredths of a Pound.			Grams.						
		Animal Food.			Vegetable Food.	Animal Food.			Vegetable Food.	Dairy Products and Eggs.	Vegetable Food.	Protein.	Fats.	Carbohydrates.	Protein.	Fats.	Carbohydrates.	Animal Food.			Vegetable Food.
		Meats, Fish etc.	Da'y pro'd's and Eggs.	Total.		Meats, Fish etc.	Da'y pro'd's and Eggs.	Total.										Meats, Fish etc.	Da'y pro'd's and Eggs.	Total.	
	Miscellaneous, Mass.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Grms.	Grms.	Grms.	%	%	%	%
A 11	Family, - - -	.07	.03	.10	.11	.13	.14	.27	.02	.03	1.03	.21	.29	1.06	95	132	481	33	14	47	53
A 1	Boarding-house, -	.11	.06	.17	.12	.31	.18	.49	.01	.07	1.13	.29	.50	1.20	132	227	545	38	21	59	41
A 7	Boarding-house, -	.09	.04	.13	.12	.19	.12	.31	.02	.04	1.11	.25	.33	1.15	114	150	522	36	16	52	48
A 2	Boarding-house, -	.11	.05	.16	.13	.30	.13	.43	.01	.06	1.15	.29	.44	1.21	132	200	549	38	17	55	45
A 9	Family, - - -	.17	.08	.25	.15	.31	.21	.52	.04	.07	1.29	.40	.56	1.36	182	254	617	42	20	62	38
	Average of 7, - -	.11	.05	.16	.12	.24	.15	.39	.02	.06	1.11	.28	.41	1.17	127	186	531	39	18	57	43
	F'ch Can'd'ns, Mass.																				
B 6	Family, - - -	.04	.02	.06	.12	.21	.06	.27	.02	—	1.09	.18	.29	1.09	82	132	495	22	11	33	67
B 4	Boarding-house, -	.09	.04	.13	.08	.49	.09	.58	.01	.03	.69	.21	.59	.72	95	268	327	43	19	62	38
B 1	Family, - - -	.10	.03	.13	.12	.33	.07	.40	.01	.03	1.12	.25	.41	1.15	114	186	522	40	12	52	48
B 5	Boarding-house, -	.10	.02	.12	.19	.47	.10	.57	.02	.01	1.21	.31	.59	1.22	141	268	554	32	7	39	61
B 10	Family, - - -	.15	.08	.23	.21	.48	.15	.63	.04	.05	1.70	.44	.67	1.75	200	304	795	34	18	52	48
	Average of 10, -	.08	.04	.12	.14	.34	.09	.43	.02	.02	1.19	.26	.45	1.21	118	204	549	31	15	46	54
	F'ch Can'd'ns, Can.																				
C 18	Boarding-house, -	.04	.01	.05	.11	.09	.08	.17	.02	—	.85	.16	.19	.85	73	86	386	25	6	31	69
C 12	Family, - - -	.05	.01	.06	.12	.07	.11	.18	.02	.02	.93	.18	.20	.95	82	91	431	28	5	33	67
C 26	Family, - - -	.09	.02	.11	.12	.10	.10	.20	.02	.02	1.13	.23	.22	1.15	104	100	522	39	9	48	52
C 24	Family, - - -	.14	.02	.16	.17	.17	.17	.34	.03	.02	1.16	.33	.37	1.18	150	168	536	42	6	48	52
C 6	Family, - - -	.08	.04	.12	.17	.08	.12	.20	.02	.04	1.09	.29	.22	1.13	132	100	513	27	14	41	59
	Average of 13, -	.07	.02	.09	.15	.10	.11	.21	.03	.02	1.14	.24	.24	1.16	109	109	527	29	8	37	63

TABLE 46.

Persons stated to be Nourished by Food of Dietaries, and Estimated Numbers of "Laboring Men at Moderate Work" who would require the same Quantities of Nutrients.

Series and No. of Dietary.	PERSONS REPORTED.	CLASSIFICATION.					Total Number of Persons.	Estimated Equivalent to Laboring Men.
		Adults.		Children.				
		Males.	Females.	15 to 6 years.	6 to 2 years.	Under 2 years.		
	Miscellaneous, Massachusetts.							
A 11	Father, mother, one other adult female, and 3 children of 5, 11, and 12 years, - - - -	1	2	2	1	—	6	4½
A 1	Boarding-house, 66 males and 11 females, - -	66	11	—	—	—	77	75
A 7	Boarding-house, 20 males and 16 females, - -	20	16	—	—	—	36	33
A 2	Boarding-house, 10 males and 60 females, - -	10	60	—	—	—	70	58
A 9	Husband and wife, - -	1	1	—	—	—	2	1 4-5
	French Canadian, Massachusetts.							
B 0	Father, mother, 2 adult children (1) and 2 children of 9 and 12½ years,	2	2	2	—	—	6	5
B 4	Boarding-house, 8 men, 7 women, and 3 children,	8	7	3	—	—	18	15½
B 1	Father, mother, and 4 adult children, one female, -	4	2	—	—	—	6	5½
B 5	Boarding-house, 6 males and 4 females, ages 16-40 years, - - - -	6	4	—	—	—	10	9½
B 10	Two brothers (2) and a sister, adults, - - -	2	1	—	—	—	3	3
	French Canadian, Canada.							
C 18	Boarding-house, 15 adults,	8	7	—	—	—	15	13½
C 12	Father, mother, and 8 children, 2 to 13 years old,	1	1	5	3	—	10	6⅔
C 26	Father, mother, and 3 children of 9, 12 and 14 years	1	1	3	—	—	5	4
C 24	Father, mother, and 2 children, 6 months and 5 years old, - - -	1	1	—	1	1	4	2½
C 6	Father, mother, and 6 children, 1 to 12 years old, -	1	1	3	2	1	8	5

(1.) One male and one female. (2.) The men, blacksmiths, were at rather severe work, hence the two with one woman are estimated as equivalent to three men at moderate manual labor.

TABLE 47.

*Summary of Statistics of Dietaries. Quantities and Costs of Foods and Quantities of Nutrients. Maximum, Minimum, and Average per Man per Day.**

QUANTITIES, COSTS, AND NUTRIENTS OF FOOD MATERIALS.	Series A. Miscellaneous, Massachusetts.			Series B. French Canadian, Massachusetts.			Series C. French Canadian, Canada.		
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
Quantities of Food Materials.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Meats, fish, etc., -	1.36	.63	.88	1.28	.46	.81	1.13	.35	.52
Milk, butter, cheese and eggs, - -	1.70	.82	1.29	1.51	.21	.70	.98	.14	.45
Total animal food, -	3.00	1.48	2.17	2.79	.67	1.51	1.68	.54	.97
Vegetable food, -	4.17	2.38	3.02	5.65	2.35	3.44	3.65	1.65	2.49
Total food, -	7.17	4.12	5.19	7.26	3.02	4.95	4.89	2.20	3.46
Costs of Food Materials.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.
Meats, fish, etc., -	24	6	11	18	6	11	9	3	5
Milk, butter, cheese and eggs, - -	12	4	6	11	3	5	7	1	3
Total animal food, -	36	10	17	29	10	16	13	5	8
Vegetable food, -	11	6	8	13	6	8	8	5	6
Total cost, - -	47	16	25	39	17	24	19	11	14
Nutrients in Food Materials.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Protein, - -	.40	.21	.28	.44	.18	.26	.33	.16	.24
Fats, - - -	.56	.29	.41	.67	.28	.45	.39	.16	.24
Carbohydrates, -	1.36	1.05	1.17	1.75	.72	1.21	1.59	.85	1.16
Total nutrients, -	2.32	1.56	1.86	2.86	1.52	1.92	2.29	1.20	1.64
Percentages of animal protein in total protein of food, - - -	% 64	% 47	% 57	% 62	% 33	% 46	% 48	% 29	% 37

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* The figures for "maximum" and "minimum" indicate the largest and smallest quantities, in any single dietary, and those for "average," the averages of all the dietaries of each series. Thus the largest quantities of meats, etc., per man per day in any of the dietaries of Series A was 1.36 lbs., the smallest 0.63 lbs., and the average of the 7 dietaries of this series examined was 0.88 lbs. The largest amount of total food in any single dietary of this series was 7.17 lbs., the smallest 4.12 lbs., and the average 5.19 lbs. That the figures for "total" do not always equal the corresponding sum (for instance, the "Total animal food," maximum, series A, is less than the sum of the figures for meats, fish, etc., and for milk, butter, cheese, and eggs) is due to the fact that the factors which would make up the sum are from different dietaries, while the figures for "total" are the maximum, minimum, etc., for individual dietaries.

Discussion of Results.—The discussion of the dietary statistics involves details of local interest, but the following quotations from the report will serve to show some of the ways in which such information can be made useful.

It will be remembered that Series A, Miscellaneous, Massachusetts, includes dietaries of factory and mill operatives, mechanics, and a few clerks, dressmakers, etc., of various nationalities, in Lowell, Lawrence, Lynn, East Cambridge, and Boston. Series B, French Canadians, Massachusetts, includes factory operatives and a few mechanics of Canadian origin, working in Massachusetts. Series C, French Canadians, Canada, includes similar people, mainly or entirely laboring classes in Canada. In other words, the people had only very moderate incomes, and the majority were factory operatives, a class of whom we ordinarily think as living on a rather low plane of material comfort. The following statements are from the report referred to:

> In the following table (48) the averages of the analyses of dietaries are succinctly set forth.

TABLE 48.

Averages of Statistics of Dietaries. Quantities and Costs of Foods and Quantities of Nutrients as estimated per man per day.

QUANTITIES, COSTS, AND NUTRIENTS OF FOOD MATERIALS.	Series A. Miscellaneous, Massachusetts.	FRENCH CANADIAN.	
		Series B. Massachusetts.	Series C. Canada.
Quantities of Food Materials.	Lbs.	Lbs.	Lbs.
Animal,	2.17	1.51	.97
Vegetable,	3.02	3.44	2.49
Total,	5.19	4.95	3.46
Costs of Food Materials.	Cts.	Cts.	Cts.
Animal,	17	16	8
Vegetable,	8	8	6
Total,	25	24	14
Nutrients in Food Materials.	Grams.	Grams.	Grams.
Protein,	127	118	109
Fats,	186	204	109
Carbohydrates,	531	549	527
Total,	844	871	745
Parts of animal protein in 100 of total protein,	% 57	% 46	% 37

From table 48 it appears that the French Canadian laboring man whose food we have examined consumes at home three and one-half pounds of food (including milk) per day. But when he comes to Massachusetts and works in a factory or engages in other manual labor, he consumes five pounds, while other laborers, factory operatives, mechanics, etc., in Massachusetts, whose dietaries have been examined, consume five and one-fifth pounds of food per man per day. The food of the French Canadian at home costs fourteen cents, but in Massachusetts he expends twenty-four cents, while the food of the other Massachusetts laborers costs twenty-five cents per day. The nutrients in the food-materials show corresponding gradations, the Canadian having one hundred and nine grams of protein per day at home and one hundred and eighteen in Massachusetts, while the other Massachusetts laborers have one hundred and twenty-seven grams. The gradations in the carbohydrates are similar, save that the differences are smaller. The amount of fats is smallest in the dietary of the Canadian in Canada, but nearly the same in those of the Canadian and other laborers in Massachusetts. That the Canadian in Massachusetts should have more fat than other laborers, while he has so much less protein, is apparently due to the larger proportion of salt pork in his meat.

A most interesting fact set forth in this table is found in the proportions of animal and vegetable food. In Canada the French Canadian has one pound of animal food—meats, fish, milk, butter, cheese, eggs, etc.; in Massachusetts he has a pound and a half, while his fellow-laborers of other nationalities have two and one-fifth pounds per man per day. There is a corresponding variation in the proportion of animal protein to the total protein of the food, the French Canadian at home having thirty-seven per cent., the same man in Massachusetts forty-six per cent., and other Massachusetts laborers fifty-seven per cent.

These figures are the expression of what we suppose to be a general law, namely, that where the conditions of life are otherwise approximately similar, as in the different countries of Europe and America, not only the total amount of food, but, more especially, the amount of meat and other animal food consumed increases with the revenue of the consumer. We regret that corresponding statistics for laboring people in the different countries of Europe are not at hand, but feel confident that the outcome would sustain the proposition just made. It is a very familiar observation of those who have noted the habits of the ordinary people in European countries like Italy, Germany, and France, that the amounts of meat they consume are very small, and statistics show that their food is very apt to be deficient in protein.

Before proceeding farther we may consider some others which have been examined, but of which the details have not yet been published. The limits of space here permit only a summary. I hope that the full details of these, and a reasonably exhaustive discussion of their results, with those of other American dietaries, may soon be given in another place.

OTHER DIETARIES OF WORKING PEOPLE IN MASSACHUSETTS.

Among the schedules furnished me by the Massachusetts Bureau of Statistics of Labor for elaboration as above described, was one of the dietary of a Boston boarding-house, the quantities of nutrients in which were very large. This was my first experience in the study of dietaries in the United States, and like other students of the subject, I had been in the way of accepting the results of European investigations as a measure of the food consumption of the laboring people in general. The dietary was far above the ordinarily accepted standards, and I feared that some error might have crept into the schedules as reported. I, therefore, omitted the dietary from the tables and averages, explained the reason for so doing to the Bureau, and suggested that the figures be withheld for consideration. When opportunity for consultation with the agent of the Bureau, who had collated the statistics of this dietary, occurred, which was not until after the report had gone to the printer, I learned that the figures obtained were in his judgment especially reliable and satisfactory. He had discussed the details fully with the keeper of the boarding house, whose accounts were very well kept and accurate, and he felt certain that there could be no error. The boarders, mostly teamsters and marble workers, were men whose labor was rather severe and who received good wages. The estimated quantities of nutrients per man per day were: Protein, 254 grams; fat, 363 grams; carbohydrates, 826 grams; and the potential energy, 7,805 Calories. The dietary is entered as No. 8 in the summary of American dietaries in table 49, beyond.

The report above referred to contains statistics of food consumption of a boarding-house in Massachusetts, which were not received in time for examination with the rest, and were hence printed without estimates of the quantities of nutrients. The boarders were laborers in a brick-yard. The statistics were obtained from books kept in such way as to warrant the greatest confidence in their accuracy. They represent the "consumption of food, etc., in a boarding-house for thirty-nine weeks by 237 men, all laborers, presenting also the average weekly consumption per man for each article, at a cost for each person of $1.30 per week. The table is compiled from original data secured by the Bureau."

Food Materials, etc., Consumed by Brickmakers in a Boarding-House.

KINDS.	AMOUNTS.	
	247 men 30 days.	One man per week.
Beef, pounds,	19,683	2.120
Mutton, pounds,	2,840	.307
Pork, barrels,	250	.027
Fish, pounds,	2,550	.275
Milk, quarts,	2,821	.305
Butter, pounds,	8,121	.878
Flour, barrels,	534	.057
Rice, bushels.	787	.085
Beans, bushels,	118	.012
Peas, bushels,	98	.010
Potatoes, bushels,	1,842	.199
Turnips, bushels,	31	.003
Onions, bushels,	81	.008
Dried apples, pounds,	1,716	.185
Molasses, gallons,	2,272	.245
Coffee, pounds,	370	.040
Tea, pounds,	600	.064
Salt, pounds,	2,925	.316
Vinegar, gallons,	262	.028
Soup, pounds,	1,708	.184

Using the results of analyses made of similar materials in this laboratory, I have estimated the nutrients and energy of this dietary per man per day, as follows: Protein, 180 grams; fats, 365 grams; carbohydrates, 1,150 grams; energy, 8,850 Calories. These figures are the largest that have ever come under my observation. As the result of careful inquiry, I could learn of no probable source of error, except that a few persons, mainly women, employed in the boarding-house may have partaken of the food; but I am informed that the number could not have been sufficient to greatly affect the estimated quantities per man per day. I have no specific information as to the strenousness of the labor, except that the work in the brick-yards in the region is counted to be severe. The dietary is included as number 9 in the tabular summary beyond.

DIETARIES COLLATED IN CONNECTICUT.

Two dietaries, one of a boarding-house and the other of a family, in Middletown, Conn., are described in detail by Mr.

Woods in the previous chapter. The boarders in the boarding-house were mainly machinists and other men earning good wages, and women engaged in moderate manual labor. In the other, the family consisted of two chemists, with the wife of one, and a female servant. The dietaries are given as Nos. 34 and 35 in the table beyond.

Dietary of Brickmakers.—At the time when the examinations of the Massachusetts dietaries were made and shortly thereafter a dietary of brickmakers, one of a well-to-do private family in Middletown and several of students in Wesleyan University were examined. The details of the calculations were carefully performed by Mr. E. W. Rockwood, assistant in chemistry, and by two advanced students who were especially interested in physiological chemistry, Messrs. J. S. Haynes and C. S. Videon.

The proprietor of a brick-yard in Middletown has kindly furnished me an estimate of the total amount of food materials furnished to his men in a day. Following the method employed in the estimates of nutrients in the Massachusetts and Canadian dietaries above, Mr. Haynes computes them to contain, per man, per day: Protein, 222 grams; fats, 263 grams; carbohydrates, 758 grams. The corresponding potential energy is 6,460 Calories. Considering that the quantities were for so short a time, and that the materials could not be weighed with laboratory accuracy, I do not quote the estimates of the nutrients as an exact measure of the amounts eaten, but rather for the sake of what is suggested by the dietary, and the condition and labor of the consumers.

The laborers to whom this large amount of food was supplied were ordinary Canadians, Irishmen, and some native Americans. Their work is rather trying, as it must be from the necessity of making as many brick as possible in the busy season, but the proprietor makes it a point to secure good workmen, and finds one of the best means of doing so is to "give them good board, which they think more of than anything else." He assures me that this is nearly all actually eaten, very little being thrown away. He says that he sometimes gets freshly-arrived immigrants at Castle Garden, New York, and that he always finds they have been accustomed to eat little or no meat, and adds: "They come to me in very poor condition, but it is wonderful to see how they pick up, even with their hard work."

Here is a case in which ordinary laborers, some of them previously underfed, have a generous diet, accomplish a large amount of muscular work and instead of losing, to all appearance, gain in physical capacity. Of course, more accurate observations would be needed to warrant decided inferences. But the case fits into the purpose of the investigations, namely, that of obtaining information which will suggest questions and methods of inquiry, and probable results. It will be referred to in a succeeding chapter.

Dietary of a Private Family.—The weighings and estimates for the dietary here reported upon, that of the family of a professor, were made by Mr. Rockwood. On the first day of January accurate account was taken of all the food materials in the house. The quantities of food brought to the house during January, February, and March, were estimated from the grocer's, butcher's and other bills. During the same period all the food left unconsumed, *i. e.*, the kitchen and table refuse, was carefully kept, weighed, and its composition estimated. On the first day of April the food materials remaining in the house were weighed. In estimating the quantities of nutrients, Mr. Rockwood used the method employed for those of the Massachusetts and Canadian dietaries, which he assisted in preparing. The quantities per man per day were:

	Protein.	Fats.	Carbohydrates.	Energy.
In Food purchased,	129 grm.	183 grm.	467 grm.	4145 cal.
In Waste,	1 "	6 "	1 "	65 "
In food eaten,	128 grm.	177 grm.	466 grm.	4080 cal.

The smallness of the waste is explained by the fact that the mistress of the house was a particularly careful housekeeper.

Dietaries of Students.—A large number of the students in Wesleyan University board in clubs. The club, which may have any number of members up to thirty, chooses one of its number as steward, and arranges with a matron to cook and serve the food which he purchases. Many of the members have to pay their way through college, the majority are obliged and the rest are content to have the cost of their board made low, even at the sacrifice of delicacies. While their diet is substantial and wholesome, they regard it as plain and economical. They are mostly from the Eastern States, and, coming from the class of families whose sons go to college, it seems fair to assume that their habits of eating formed at home would not differ materially from those of the more intelligent classes of people in that part of the country. While the habits of many are sedentary rather than active, they, nevertheless, take considerable muscular exercise. In this respect they are, I suppose, very much like the students of other Eastern colleges. They are given to athletic sports in pleasant weather. Out of two hundred and fifty, sometimes seventy or more may be seen at once on the campus playing tennis and base ball. They could hardly be credited with as much muscular exercise on the average as "laboring men doing moderate work," for whom standard rations in the next chapter are calculated, and they would, therefore, without doubt, require somewhat less of protein as well as of the other nutrients in their food. I should think it fair to reckon their requirements as approaching closely to those of the man with moderate exercise.

Mr. Haynes took the accounts of one of these clubs for a term of three months, and computed the amounts of the several kinds of food materials purchased, and the quantities of nutrients.

The figures thus obtained represent what the students paid for, rather than the amounts actually consumed. The steward and some of the members of the club were of the opinion, however, that the amount of waste, that is to say, the material thrown away, was very small. "All the meat and other available food that was not actually served to the men at the table," said the steward, "was carefully saved and made over into hash and croquettes." Indeed, for that matter, "men who work their way through college cannot afford to throw away their food. It costs too much." But on investigating the matter more closely it appeared that a portion of the material served was left upon the plates and found its way into the garbage barrel or was given to an indigent colored woman, who came for it regularly. At Mr. Haynes' suggestion, the steward had the amounts rejected during one week weighed. Its composition was estimated and the waste calculated. As shown in the summary below, the estimated quantities were:

In Food purchased :—Protein, 161 grams; energy, 5345 calories.
In Waste :—Protein, 138 grams; energy, 520 calories.

The following term an examination of the dietary of the same club was made by Mr. Videon. Another steward was then in charge. He had learned of the excessive amounts of food in the former dietary, and planned to reduce the quantities. This was done largely by diminishing the meats. He states that he did not apprise the club of the change, and that it was not noticed. As he put it, "The boys had all they wanted, and were just as well pleased as if they had had more." The quantities of nutrients in both dietaries were estimated by the method already described. The waste in the second dietary was estimated with some care. In this, as in the first, it is assumed that the difference between the food purchased and the waste represents the actual consumption. The results were:

Dietaries of the M—— Club.

		Protein.	Fats.	Carbohydrates.	Potential Energy.
		Grams.	Grams.	Grams.	Calories.
First dietary,	Food purchased,	161	204	680	5,345
	Waste,	23	20	58	520
	Food eaten,	138	184	622	4,825
Second dietary,	Food purchased,	115	163	460	3,875
	Waste,	11	27	39	460
	Food eaten,	104	136	421	3,415

These dietaries are included as Nos. 37*a* and *b*, and 38*a* and *b*, in table 49, beyond.

Mr. Videon also examined the dietary of a club of which he was a member. To make the data as accurate as practicable, he weighed the food materials instead of taking the weights from the bills, as was done with the other students' dietaries. The waste was also weighed. The members of the club were in moderate circumstances and felt the necessity of economizing, but at the same time intended to have an abundance of wholesome food. Mr. Videon's attention, and through him that of the club, had been called to the waste in other dietaries. This, I mistrust, is the explanation of the smallness of the waste here. The results were:

Dietary of the N—— Club.

	Protein.	Fats.	Carbohydrates.	Potential Energy.
	Grams.	Grams.	Grams.	Calories.
Food purchased,	141	160	503	4,130
Waste,	1	2	none.	25
Food eaten,	140	158	503	4,105

Finally, Mr. Videon examined the dietary of the College foot-ball team at a time when they were in active training and boarding in a club by themselves. Their exercise was vigorous and at times severe, but the examination was made near the close of the foot-ball season when, in the judgment of members of the club, they were eating rather less heartily than they had done earlier in the season. The quantities, as estimated, were:

Dietary of Foot-Ball Team.

	Protein.	Fats.	Carbohydrates.	Potential Energy.
	Grams.	Grams.	Grams.	Calories.
Food purchased,	194	312	578	6,070
Waste,	13	20	21	330
Food eaten,	181	292	557	5,740

U. S. Army and Navy Rations.—It is difficult to compute exactly the food consumption by soldiers in the U. S. army, because the men have more or less of opportunity to select or add to their food by commuting purchase or otherwise, so that the food actually used varies more or less from the regulation rations. The best data for calculations I have found are those contained in Circular No. 8 of the Surgeon-General's office, U. S. A. From these Mr. Woods has computed the nutrients and energy as stated in table 49.

Table 49 summarizes the results of the examinations of dietaries above referred to. No other studies of the kind in the United States have come to my notice.

TABLE 49.

SUMMARY OF AMERICAN DIETARIES EXAMINED.

Estimated Nutrients and Potential Energy per Man per Day.

Reference Number.	DIETARIES.	Number of Persons.	NUTRIENTS.			Potential Energy.
			Protein.	Fats.	Carbohydrates.	
	COLLATED BY MASS. LABOR BUREAU. *Series A. Miscellaneous. Factory Operatives, Mechanics, etc., Massachusetts.*		Grms	Grms	Grms.	Calories
1	A 1. Boarding-house, Lowell } boarders	77	132	227	545	4,890
2	A 2. Boarding-house, Lowell } operatives in	70	132	200	549	4,650
3	A 5. Boarding-house, Lowell } cotton mills,	150	105	136	477	3,650
4	A 7. Boarding-house, Lynn, shoe factory operatives, dressmakers, clerks, etc., -	36	114	150	522	4,000
5	A 13. Boarding-house, Lawrence, mill operatives, - - - - - - - -	80	127	195	523	4,480
6	A 11. Family, East Cambridge, father glass-blower, - - - - - - -	6	95	132	481	3,590
7	A 9. Family, Boston, husband, machinist, -	2	182	254	617	5,640
	Average of Nos. 1–7, - - -	**421**	**127**	**185**	**531**	**4,415**
8	A 17. Boarding-house, Boston, teamsters, marble workers, etc., at severe work, -	12	254	363	826	7,805
9	A 18. Boarding house, brickmakers at severe work, - - - - - - - -	237	180	365	1,150	8,850
	Average of Nos. 1–9, - -	**670**	**147**	**225**	**632**	**5,285**
10	A 14. } French Canadian families, - }	4	132	236	750	5,810
11	A 15. } in North Cambridge, - - }	5	100	173	545	4,250
12	A 16. } fathers, brickmakers, at severe work, }	5	95	145	514	3,845
	Average of Nos. 10–12, - -	**14**	**109**	**185**	**603**	**4,635**
	Series B. French Canadians. Factory Operatives, mechanics, etc., Massachusetts.					
13	B 1. Family, Lawrence, mill operatives, -	6	114	186	522	4,340
14	B 4. Boarding-house, Holyoke, operatives in paper mills, - - - - - -	18	95	268	327	4,220
15	B 5. Boarding-house, Holyoke, factory operatives, - - - - - - - -	10	141	268	554	5,340
16	B 6. Family, Holyoke, mill operatives, -	6	82	132	495	3,595
17	B 13. Family, Worcester, mill operatives, -	10	114	127	504	3,715
18	B 12. Family, Worcester, father, printer, -	4	118	177	509	4,215
19	B 10. Family, Lowell, blacksmiths at hard work, - - - - - - - -	3	200	304	795	6,905
	Average of Nos. 13–19, - -	**57**	**123**	**209**	**529**	**4,620**
	Average of Nos. 10–19, - -	**71**	**119**	**202**	**552**	**4,625**

Table 49.—*(Continued.)*

Reference Number.	Dietaries.	Number of Persons.	Nutrients.			Potential Energy.
			Protein.	Fats.	Carbohydrates.	
	Series C. French Canadians, Canada. All laboring people.		Grms	Grms	Grms.	Calories
20	C 1. Boarding-house, Montreal, - -	8	100	77	573	3,475
21	C 5. Family, Montreal, - - - - -	3	141	177	723	5,190
22	C 6. Family, Quebec, - - - -	8	132	100	513	3,575
23	C 9. Family, Quebec, - - - -	8	136	127	641	4,365
24	C 11. Family, St. John, - - - -	5	123	114	582	3,950
25	C 12. Family, St. John, - - -	10	82	91	431	2,950
26	C 13. Boarding-house, Sorel, - - -	10	91	73	514	3,160
27	C 14. Boarding-house, Sorel, - - -	12	86	86	473	3,090
28	C 18. Boarding-house, Rivière du Loup, -	15	73	86	386	2,680
29	C 21. Family, St. Hyacinth, - - -	6	105	86	468	3,150
30	C 24. Family, Sherbrooke, - - -	4	150	168	536	4,375
31	C 25. Family, Richmond, - - - - -	8	86	91	477	3,155
32	C 26. Family, Richmond, - - - -	5	104	100	522	3,495
	Average of Nos. 20–32, - -	**102**	**108**	**106**	**526**	**3,585**
	Examined in Middletown, Conn. *Working people.*					
33	Boarding-house, brickmakers at hard work,		222	263	758	6,460
34*a*	Boarding-house, well paid machinists, etc., - food purchased	21	126	188	426	4,010
34*b*	food eaten, -	21	103	152	402	3,490
	Families of Professional Men, College Students.					
35	Family of chemist, - - - - -	4	118	103	430	3,205
36*a*	Family of college profes'r, food purchased,	4	129	183	467	4,145
36*b*	food eaten, -	4	128	177	466	4,080
37*a*	M— Club, students, two dietaries of same club, - - first dietary food purchased,	24	161	204	680	5,345
37*b*	food eaten, -	24	138	184	622	4,825
38*a*	second dietary food purchased,	31	115	163	460	3,875
38*b*	food eaten, -	31	104	136	421	3,415
39*a*	N— Club, students, - food purchased,	3	141	160	503	4,130
39*b*	food eaten, -	3	140	158	503	4,105
40*a*	Students, foot-ball team, food purchased,	12	194	312	578	6,070
40*b*	food eaten, -	12	181	292	557	5,740
	Averages of Nos. 1–9 and 33–34, wage-workers in Massachusetts and Connecticut (food purchased), - - - - -		**152**	**225**	**625**	**5,275**
	Averages of 35–39, professional men and college students, - - - food purchased,		**133**	**163**	**508**	**4,140**
	waste, - -		**7**	**11**	**19**	**214**
	food eaten, -		**126**	**152**	**489**	**3,926**
41	U. S. army ration, - - - - -		120	161	454	3,850
42	U. S. navy ration, - - - - -		143	184	520	5,000

EUROPEAN DIETARIES.

In Europe very extensive studies of dietaries have been made. In the majority of the cases the quantities of the food materials have been estimated, or more or less roughly weighed, and the composition calculated from the results of analyses of similar materials. In a number, however, the food materials have been weighed with considerable care, and in a still smaller number the food materials have been analyzed. In numerous instances, the quantities of protein digested and transformed in the body have been determined and compared with the total protein of the food by nitrogen determinations in the food, urine and fæces. In half a dozen or more experiments with men, the whole income and outgo have been determined by the respiration apparatus.

To set forth all the European results would require more space than would here be allowable. Table 53 summarizes a sufficient number of the most thoroughly studied dietaries, to illustrate the results obtained and serve for comparison with the American dietaries here reported. The figures are mostly German, for the reason that the larger part of the best work in this line has been done in Germany. I include some results of such studies in England, Sweden, and Denmark that have come to my notice, but have not attempted to collate figures from other European countries.*

English Dietaries.—Nos. 1–5 are those of under-fed people of the poorer classes. The twelve dietaries were those of seamstresses, weavers, glove makers, cotton-mill operatives, and shoemakers in England, and agricultural laborers in England, Scotland, and Ireland. These figures are as computed by Meinert[1] from the report of a government commission in 1863, on the condition of the poorer classes. I infer this to be the same report of which Sir Lyon Playfair says[2] that the data are reliable for what they profess to be, as giving an insight into the modes of living of artisans, but are not based upon accurate weights and measurements of food actually consumed. The worst nourished class were the London seamstresses, whose wages did not average more than three shillings and nine pence per week.

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* Discussions of the subject with more or less of compilations of later results may be found in Voit's *Physiologie des Allgemeinen Stoffroechsels und der Ernährung*, which forms Part I. of the Sixth volume of Hermann's *Handbuch der Physiologie;* in Meinert's *Armee und Volksernährung;* and in König's *Chemie der Menschlichen Nahrungs und Genussmittel*, third Edition, Volume I. Table 53 includes, however, the results of studies published since the issue of these volumes.

[1] Armee-und Volksernährung, II., 230. [2] Chem. News, XI., 223.

Nos. 5, 6, 7, 8, and 10, are those estimated by Sir Lyon Playfair* from the actual weights of the food consumed by individuals; Playfair speaks of the engineers (soldiers) of No. 11 as "laborers in time of peace actively occupied either in the construction of field works, or pursuing their avocations as artisans," and regards the dietary as "the most complete evidence we possess [at the time, 1864–5] of the requirements of food for laboring men doing a fair, but not excessive, amount of work in 24 hours; when these soldiers are at light labor, they are found to take less."

Danish and Swedish Dietaries.—Nos. 10 and 11 are reported by Jürgesen.† No. 10 is that of a physician in Stockholm, 37 years old. The food in this case, as in No 11, consisted of milk, meat, fish, bread, cheese, butter, and beer. The investigation was made in January and February. No. 11 is that of the wife of the physician just named, 35 years old, principal of a girls' school; time of investigation, May.

Nos. 12, 13, and 14 are reported by Hultgren and Landgren.‡ The food materials were carefully weighed as used; the composition was estimated from analyses published by König and Almen. For substances of which no reliable figures for composition were available, as pastry, etc., special analyses were made.

No. 12 represents the average of five dietaries of as many medical students in Stockholm, from 22–27 years of age, busily engaged in study and laboratory work. The examinations were made in the winter. The experimental periods ranged from 8 to 16 days; the protein per person per day from 103 to 163 grams, and the energy from 2,800 to 3,375 Calories.

No. 13 represents the average of six dietaries of four healthy men, a metal worker, a blacksmith, a carpenter, and a farm laborer, from 28 to 46 years of age, at moderately hard work and earning good wages. The food included meat, fish, milk, etc., and alcohol in beer or stronger spirits. The alcohol averaged 22 grams per man per day, and is estimated as equivalent in fuel value to 37.8 grams of carbohydrates. The protein ranged from 105 to 166 grams and the energy from 2,895 to 3,510 Calories, per man per day. The diet of this group of men is regarded by the authors as characteristic in respect to nutrients and energy for Swedish laboring men at moderate work *("Mittelere Arbeit")*.

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* Chem. News, XI., 223. † Zeitsch. f. Biologie, 22, 489. ‡ Untersuchung über die Ernährung bei freigewählter Kost; Hygiea, 1889, Festband, No. 11, and Untersuchung über die Ernährung schwedischer Arbeiter. Stockholm, 1891.

No. 14 represents the average of five dietaries of five vigorous men, a stone mason, a bricklayer, a carpenter, a wood-sawyer, and a farm laborer, from 31 to 54 years of age, at very hard work and earning good wages. The food was similar to that of No. 13. The alcohol averaged 24.2 grams per man per day. It was estimated as equivalent to 41.3 grams of carbohydrates, and included in the estimates of carbohydrates and energy as in No. 13. The protein ranged from 128 to 246 grams, and the energy from 3,655 to 5,580 Calories, per man per day. The authors regard the diet of this group of men as fairly representative of that of Swedish workingmen at severe work.

German Dietaries.—Nos. 15–23 are dietaries of laboring people of the poorer classes, living, No. 23 near and the rest in, the city of Leipsic, Saxony. The inquiry was conducted in part, at least, and presumably the whole, in 1878–1880, by Dr. Meinert,* with the purpose of learning something of the conditions of life and especially the food of people of small incomes in Germany. It was evidently conducted with no little care and thoroughness. For each dietary the food was weighed during a period of five or seven days, with such detail as to show the amounts of each food material per meal. Allowance was made for the waste in one case, at any rate, as stated in the report and presumably for all, so that the quantities given are those actually consumed. No statement is made of analyses especially executed for the investigation, and it is to be inferred that the composition of the food was estimated from standard analyses. The quantities of nutrients and costs of food are estimated per adult per day. In the cases where there were children the equivalent number of adults was assumed for the calculations. The amounts of food of different kinds eaten per meal and per day, the amounts, costs of the several kinds of food, and of the whole food of each dietary, the incomes of the people and their ways of living, were observed and reported. While the quantities of nutrients imply straitened circumstances in most of the cases, the details in some are decidedly pathetic. The space here will allow only a brief summary of some of the more important points.

No. 15.—Girl in cigar factory, 25 years old, earning an average 5 marks per week and boarding with her mother, who earned 3 marks per week by washing. Their food consisted mainly of bread, potatoes, a little rice, occasionally vegetables, meat 250 grams for two persons twice a week, or half a pound a week for each person, and coffee. In lack of fuel for heating the coffee, hot water from a neighboring factory was used. The description says, "it is not strange that with food so poor in protein both mother and daughter are frail and sickly, nor that, as the girl told me in tears, they often went supperless to bed. * * The girl is the mother of a child six months old; * * for board and lodging of herself and child she pays 3½ marks per week, and thus has left from her wages for clothing and other expenses for herself and child 1½ marks per week, a sum which, while it does not justify, explains her increasing it by other means." The amounts and composition of the food are computed for the young woman and her mother, so that the figures represent the average for the two.

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* Armee-und Volksernährung, II., 190.

No. 16. Girl working in a printing office. She was was 29 years old, her wages averaged 5 marks per week, she lived with another girl and a child of the latter in a room ten feet square. In the three winter months of 1879–80, she had only bread and butter and coffee, and for dinner daily from 1¼ to 2½ cents worth oɪ sausage, and even on this fare used up $5.50 of previous savings. The amount, composition, and cost of the food were estimated for the two girls together, so that the figures represent the average. "What wonder," says Dr. Meinert, "that young women whose moral energy and intellectual powers are reduced by such a starvation diet are unable to withstand temptation." He boarded with the family of No. 16.

No. 17.—Widow, with five children, aged 5½, 8, 10, 12 and 14 years, respectively. She supported herself and children by plaiting straw and taking boarders. The food consisted of bread, beef fat, potatoes, vegetables, and occasionally meat. Family estimated equivalent to four adults.

Nos. 18 and 20.—No. 18, girl 24 years old, in paper factory, wages 9 marks; sister, 21 years, seamstress, wages 8 marks per week. No. 20, brother of preceding, 28 years old, painter, wages 18 marks per week. These persons lived with their invalid mother in a fifth-story apartment consisting of a living room, a sleeping room and kitchen. Dr. Meinert says that with their earnings these people might have had much better food. "The appearance of the two girls, however, explained the scantiness of their diet. Their clothing, especially that of the seamstress, was much finer than their position and income warranted, and formed a sadly striking contrast to the appearance of the mother and the pitiable dwelling in which the people lived. The food included meat daily. Account was taken of the food of the man and of that of the women separately, the man having more than the women.

No. 19 and 21.—No. 21, family of cabinet maker, consisting of father and six children, aged ⅓, 3, 7, 9, 11 and 14 years, and father's sister (No. 19), a girl of 18, working in a bookbindery. The cabinet maker earned 18 marks and the sister 9 marks per week. The nine persons lived in an apartment consisting of two rooms and a closet holding a cook stove. The sister paid for lodging, breakfast and dinner 3½ marks (84 cents) per week and purchased bread and butter extra. The wife and children were under-sized, pale and weakly.

No. 22.—Family of druggist's clerk, consisting of father, mother and two daughters, aged 16 and 12. They are spoken of as thoroughly good people. The annual income was 1,180 marks. Their food was better than the preceding. It included more variety ; vegetables, butter and meat were eaten daily, indeed the family had meat, eggs or cheese once and often twice a day. As the man's labor was light, Dr. Meinert regards his diet as sufficient for his needs.

No. 23.—Family of farm laborer near Leipsic, consisting of father, mother and four children, from 5 to 14 years old. The six persons are counted as equivalent to four adults. The food consisted mainly of bread, beef fat and potatoes, with a little milk, and for one meal in the week, Sunday dinner, meat.

The final statistics are summarized in table 50 on the next page.

No. 24, reported by Boehm[1], was the dietary of a family of the poorer class, consisting of father, mother and a child five years old, the mother and child were reckoned equivalent to one man.

No. 25, reported by Forster[2], was the dietary of a very poor woman, who was at that time tolerably robust and at rather hard work, but afterwards died of consumption.

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[1] Quoted by König, Nahrungsmittel 3te Aufl. I, 163. [2] Zeitsch. f. Biologie IX, 1873, 381.

TABLE 50.

Food Materials and Costs per Adult per Day.

Reference Number.	DIETARIES.	Food Materials.	NUTRIENTS.				COST.	
			Protein.		Fats.	Carbohydrates.		
			Total.	Digestible.				
		Grms.	Grm.	Grm.	Grm.	Grms.	Pfg.	Cts.
15	Girl in cigar factory, - -	839	52	42	53	301	34	8.2
16	Girl in printing office, - -	1202	65	54	39	303	43	10.3
17	Woman at straw plaiting, -	1504	72	56	56	440	40	9.6
18	Girl in paper fac'y and seamst's,	842	56	47	51	229	36	8.6
19	Girl in bookbindery, - -	1062	61	49	41	347	36	8.6
20	Printer, - - - -	1195	87	73	64	366	48	11.5
21	Cabinet maker, - - -	1271	77	62	57	466	46	11.0
22	Druggist's clerk, - - -	1129	71	59	69	351	47	11.3
23	Farm laborer, - - -	1394	80	61	37	504	30	7.2

Nos. 26–29, reported by Voit[1]. The invalid was reduced by stomachic catarrh to 95 lbs., and lived for a year on a daily diet of 6 eggs and 250 grams (0.55 lbs.) of toast. No. 27.—Later the appetite improved, the food was increased to 12 eggs and 375 grams of toast, or equivalent biscuit, rice, etc. No. 28; the weight gradually increased to 126 lbs., at which point it was maintained with a daily diet of 8 eggs and 437 grams (0.96 lbs.) of toast. No. 29.

Nos. 30 and 31 are dietaries reported by Forster[2] of aged persons in a hospital in Munich for people incapable of self-support.

Nos. 32 and 33 represent observations by Prof. Benecke[3] of the University of Marburg upon himself. He was in decidedly active mental and light physical work, had about 3 hours' exercise in the laboratory and 8 hours' sleep. With a mixed diet of meat, milk, bread, etc., containing the nutrients of No. 32, his weight decreased 451 grams (1 lb.) during an experiment of 14 days. From determinations of nitrogen in food and excreta, he estimated that the dietary of No. 33 would have sufficed for his needs.

No. 34 represents the dietary of Prof. Ranke[4] of the University of Munich in an experiment upon himself, in which the total income and outgo were determined with a respiration apparatus. With very little physical exercise these quantities just sufficed him for the maintenance of his body without gain or loss.

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[1] Untersuchung der Kost, 211. [2] Loc. cit. and König, Nahrungsmittel I, 170. [3] Zur Ernährung des gesunden Menschen, 291. [4] Ernährung des Menschen, 230.

Nos. 35–37 were reported by Forster[1]. The Munich lawyer, No. 33, was in moderate circumstances, but able to have all the food that health demanded; the quantities here given are one-third of those consumed by a family of three adults. One-fourth of the carbohydrates of the food of the physician was taken in beer.

Nos. 32–37 were the dietaries of professional men in comfortable circumstances. Their food differed from that of the preceeding and most of the succeeding dietaries in that it had much more of meat and other animal foods, and was hence more completely digestible; and that it had more variety, which made it more palatable.

Nos. 38–40 were also reported by Forster[1]. The mechanic of No. 38 was connected with a laboratory, was in very comfortable circumstances, had considerable animal food, and very light, muscular work.

No. 41 represents the average result of examinations by Voit[2], of the food of three well paid mechanics in Munich. It consisted of meat, bread, other vegetable food, and beer.

No. 42 is the average of two dietaries of locksmiths, seven of carpenters, and three of coopers in Bavaria, given in a Royal Bavarian Commission report[2].

No. 43 is the average of five dietaries of Bavarian farm laborers reported by the same commission.

The figures for the individual dietaries of which Nos. 42, 43 and 45 express the averages, are as follows. The protein in the mechanics' dietaries varies from 47 to 183 grams, and the energy from 1,690 to 5,285 Calories. I have not the original data at hand, but the source would seem to vouch for their reliability. The range is very wide, but I am inclined to think not wider than might be found among people of similar occupation in ordinary communities.

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[1] Loc. cit. and Meinert, Armee-und Volksernährung I, 112. [2] Untersuchung der Kost, 28.

TABLE 51.

Dietaries of Workingmen in Bavaria.

	NUTRIENTS.			Potential Energy.
	Protein.	Fats.	Carbohydrates.	
	Grams.	Grams.	Grams.	Calories.
Locksmith,	109	41	407	2,495
Locksmith,	78	12	331	1,790
Carpenter,	149	25	974	4,835
Carpenter,	163	30	1,058	5,285
Carpenter,	173	59	513	3,360
Carpenter,	183	52	761	4,355
Carpenter,	65	22	228	1,405
Carpenter,	99	52	585	3,290
Cooper,	124	22	651	3,380
Cooper,	47	7	350	1,690
Cooper,	147	50	409	2,745
Average of 11 dietaries of mechanics,	**122**	**34**	**570**	**3,150**
Farm laborer,	131	61	609	3,600
Farm laborer,	123	61	557	3,355
Farm laborer,	189	63	683	4,160
Farm laborer,	95	33	304	1,940
Farm laborer,	147	59	559	3,445
Average of 5 dietaries of farm laborers,	**137**	**55**	**542**	**3,300**
Brewery laborers,	197	63	897	5,070
Brewery laborers,	122	34	674	3,580
Brewery laborers,	85	32	728	3,630
Brewery laborers,	116	61	566	3,365
Brewery laborers,	223	113	909	5,690
Average of 5 dietaries of brewery laborers,	**149**	**61**	**755**	**4,270**

No. 44 is the average result of examinations by Steinheil[1] of the food of miners near Ems, Prussia, at severe work. The food included meat, bread, potatoes, beans, and other vegetables in considerable variety, and butter.

No. 45 is the average of six dietaries of Bavarian brewery laborers, reported by the Bavarian Commission above mentioned. Their work is very severe, and they are noted for consuming large amounts of food, of which beer furnishes a considerable proportion of the carbohydrates.

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[1] Zeitsch. f. Biol. XIII, 1877, 415. Quoted by König, loc. cit. 156, and Meinert, loc. cit. II, 226.

No. 46 is the dietary reported by Ranke[1] of a large number of Italian brickmakers working near Munich, during the summer. Several hundred were in charge of a contractor who provided them with food and, as the description implies, was himself paid in proportion to the amount of work done. The labor was decidedly severe. The food consisted mainly of maize meal and cheese. Using the amounts per man as stated by the contractor and estimates of composition, Prof. Ranke calculated the nutrients as here given.

No. 47. This represents the average of six dietaries examined by Höfler of farm laborers in the district of Tölz, in upper Bavaria. The dietaries are included in a very interesting description of the region and the people[2]. The author says in speaking of the peasants of the district and their very unusually ample nourishment :

"The influence of their food upon their bodily development is very noticeable. The people are tall, extremely strong and sinewy; they are not fat, but their organic albuminoids [muscular as distinguished from fatty tissue] are well developed. * * Really "fat" men, that is to say, men with large deposits of fat in the body, are rare among the peasantry of this region. They have large and muscular frames and are among the best built men in the army enlistment rolls. * * Aside from their severe work a still further reason for the peculiarity of their food [large total amount and especially large quantities of fat] is found in the climate. * * The low temperature and the constant wind make the large amounts of fat a necessity. * * People who have to endure such ranges of temperature as prevail here, without especial protection by clothing, and not suffer in health, must be enabled to regulate the bodily warmth by large supplies of easily combustible fats and carbohydrates in the food."

The food consists of bread, flour, potatoes, more or less garden vegetables, milk, cheese, grease, and butter. The protein, outside that of the bread and flour, comes mainly from milk, cheese and curd, the fats from grease and butter which are consumed in large quantities, and the carbohydrates from wheat, barley and potatoes. Sugar is little used because of its cost. The description does not state how the dietaries were estimated, but only gives the quantities of nutrients as stated beyond.

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[1] Zeitsch. f. Biologie XIII, 1877, 130. [2] Der Isarwinkel, Munich, 1891, pp. 63-72.

No. 48 is the average of three dietaries of lumbermen, one from Tölz as reported by Höfler, and two from other parts of upper Bavaria, as reported by Liebig. These are in size and amounts of fat and of energy entirely exceptional among the European dietaries of which I have been able to find record, and rank even with the larger, though they are far from approaching the largest, of the American dietaries given in the previous pages. Of the peasantry in the region where the two dietaries of lumbermen by Liebig were taken, Prof. Ranke says:

"In contrast to the conditions prevalent elsewhere in Germany, the food of the country people in the Bavarian highlands and mountains is very ample, and although potatoes have not become the principal food material here, the food is chiefly vegetable. The famous peasant of the Bavarian mountain region, the genuine "Haberfeldtreiber," as he proudly calls himself, eats meat, in accordance with time-honored usage, only on the four great holidays of the year. He lives upon "*Schmalzkost*," that is to say, simple preparations of flour with which large quantities of fat are incorporated. To these he adds such materials as sourkraut and dried apples or peas. The food of these powerful peasants is so generous as to explain their herculean development of muscle, their enviable vigor, and their consciousness of strength, which often leads to excess. * * It is likewise a current observation by people in the Tegernsee Mountains that the lumbermen can do the more work, the larger their appetites are."

In comparing the dietaries of the Bavarian lumbermen, as reported by Liebig, with other European dietaries, I have sometimes, in my own mind, questioned whether the figures were entirely reliable as exponents of the eating habits of the class to which the men belonged. In matters of larger importance some of Liebig's doctrines have been doubted, only to be confirmed by the results of later inquiry. In this minor, though interesting, matter of detail the teaching of the great master is substantiated by the figures which Höfler cites. It would certainly be a valuable contribution to the science of nutrition if a number of these peasant dietaries could be thoroughly studied.

Table 52 herewith summarizes the data of the dietaries just mentioned.

TABLE 52.

Dietaries of Men in Bavarian Highlands.

OCCUPATION AND LOCALITY.	NUTRIENTS.			Potential Energy.
	Protein.	Fats.	Carbohydrates.	
Farm Laborers.	Grams.	Grams.	Grams.	Calories.
Jachenau, Tölz, average of 3 estimates. Höfler,	161	195	467	4,390
Gaissach, Tölz, average of 2 estimates. Höfler,	166	201	734	5,560
Kirchbichl, Tölz, one measurement. Höfler,	85	210	438	4,095
Average of 3 dietaries of farm laborers. Höfler,	**137**	**202**	**546**	**4,680**
Lumbermen.				
Jachenau, Tölz. Höfler,	144	358	606	6,405
Reichenhall Mountains. Liebig,	112	309	691	6,165
Oberaudorfer Mountains. Liebig,	135	208	876	6,080
Average of 3 dietaries of lumbermen,	**130**	**292**	**724**	**6,215**

No. 49–52. Army rations, like other dietaries, are decidedly variable. The figures here are borrowed from very extensive compilations by Meinert[1]. No. 49 is the average of four estimates by Voit, Artmann, Hildersheim and Meinert, respectively. No. 50 is the average of three estimates by Artmann, Hildersheim and Meinert. No. 51 is an extraordinary ration for soldiers in active service in the field.

German army management, from Frederick the Great to William and Moltke, has recognized the fundamental principle that soldiers to fight well must be well fed. No. 52 is therefore especially interesting as a ration ordered shortly after the outbreak of the Franco-German war, at the time of the terrible marching and fighting which brought the victories at Worth, Metz and Sedan.

Of the standards for dietaries in the table, those of Playfair[2] are based upon observations above referred to. Those of Wolff, Moleschott and Voit are as given by the last named investigator[3].

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[1] Armee-und Volksernährung, passim. [2] Chem. News, 1865, 222. [3] Hermann's Handbuch der Physiologie, V., 518 et seq.

TABLE 53.
European Dietaries.

Reference Number.	DIETARIES.	NUTRIENTS.			Potential Energy.
		Protein.	Fats.	Carbohydrates.	
	ENGLISH. *Scantily Nourished.*	Grms	Grms	Grms	Calories
1	Sewing girl, London, wages 93 cts. per week,* -	53	33	316	1,820
2	Weaver, Coventry,* - - - - - - -	60	28	398	2,140
3	Agricultural laborer, England,* - - - -	96	48	517	2,960
4	Agricultural laborer, Ireland,* - - - -	92	42	519	2,895
5	Average of twelve dietaries of working people of poorer classes in England, Scotland and Ireland,*	**78**	**41**	**458**	**2,580**
	Well Nourished Men at More or Less Active Work.				
6	Fully fed tailors. Playfair, - - - - - -	131	39	525	3,055
7	Hard worked weavers. Playfair, - - - - -	151	43	622	3,570
8	Blacksmiths at active labor. Playfair, - - - -	176	71	667	4,115
9	Royal Engineers, laborers at active work. Playfair,	144	83	631	3,950
	DANISH AND SWEDISH.				
10	Physician, Copenhagen. Jürgesen, - - - -	135	140	239	2,835
11	Wife of above. Jürgesen, - - - - - - -	95	107	220	2,290
12	Medical students, Stockholm, Hultgren and Landgren, - - - - - - - - - -	127	114	300	3,035
13	Mechanics, etc., Sweden, at moderate work, Hultgren and Landgren, - - - - - - -	134	79	523	3,435
14	Mechanics, etc., Sweden, at severe work, Hultgren and Landgren, - - - - - - -	189	110	714	4,725
	GERMAN.				
	(No. 15–23. Working people in Leipsic, Saxony, scantily nourished. Dietaries examined by Meinert.)				
15	Girl in factory, wages $1.20 (5 marks) per week; pale and sickly; food mostly bread and potatoes; half a a pound of meat per week; cost of food 8.2 cts. per day, - - - - - - - - -	52	53	301	1,940
16	Girl in printing office, Leipsic; wages $1.20 per week; food similar to preceding; cost 10.3 cts. per day, - - - - - - - - - -	65	39	303	1,870
17	Widow, straw plaiter, with five children; food mostly bread and potatoes, occasionally meat; cost of food 9.6 cts. per day, - - - - - -	72	56	440	2,620
18	Two girls, one 24 years old, in paper factory; wages $2.16 (9 marks); the other 21 years, seamstress; wages ($1.92 (8 marks) per week; cost of food 8.6 cts. per day, - - - - - - - - -	56	51	229	1,640
19	Girl, 18 years old, in bookbindery; wages $2.16 per week; cost of food 8.6 cts. per day, - - -	61	41	347	2,055
20	Painter, wages $4.32 per week; unmarried; cost of food 11.5 cts. per day, - - - - - -	87	64	366	2,450
21	Cabinet-maker, wages $1.92 per week; with wife and six children; cost of food 11.0 cts. per day, -	77	57	466	2,760
22	Druggist's clerk, with wife and two children; annual income $283.00 (1,180 marks); very little physical exercise; cost of food 11.3 cts. per day, - - -	71	69	351	2,370
23	Farm laborer near Leipsic, with wife and four children; food mainly vegetable; cost of food 7.2 cts. per day, - - - - - - - -	80	37	504	2,740

* As computed by Meinert. The average includes Nos. 1–4.

TABLE 53.—*(Continued.)*

Reference Number.	DIETARIES.	NUTRIENTS.			Potential Energy.
		Protein.	Fats.	Carbohydrates.	
	GERMAN—*(Continued.)*	Grms	Grms	Grms	Calories
24	Farm Laborer, Prussia, very poor; diet mostly vegetable. Boehm,	83	17	573	2,845
25	Laboring woman of poorer class, Munich; vigorous, but at rather hard work; food hardly adequate. Forster,	76	23	334	1,895
	Average of Nos. 15–25, 11 dietaries of scantily nourished laboring people,	**71**	**46**	**383**	**2,290**
26	Monk, Trappist in cloister; vegetable diet. Voit,	68	11	469	2,305
27	Invalid, weight 95 lbs. Voit,	77	32	183	1,364
28	Same, appetite improved; weight gradually increased to 126 lbs.,	134	63	275	2,263
29	Same, kept at 126 lbs.,	118	45	321	2,219
30	Old woman, Munich, doing no work. Forster,	80	49	265	1,870
31	Old man, Munich, doing no work. Forster,	92	45	332	2,155
32	Prof. Beneke, Marburg, active mental work, light physical exercise; diet not quite sufficient to maintain bodily condition,	90	79	285	2,275
33	Same, diet estimated sufficient for normal maintenance,	94	109	285	2,570
34	Prof. Ranke, Munich, very little exercise,	100	100	240	2,325
35	Lawyer, Munich. Forster,	80	125	222	2,400
36	Young physician, Munich. Forster,	127	89	362	2,830
37	Young physician, Munich. Forster,	134	102	292	2,695
	Average of Nos. 33–37, 4 dietaries of well-to-do professional men, with light muscular exercise,	**107**	**105**	**280**	**2,565**
38	Mechanic, Munich, 60 years old, in comfortable circumstances; light work. Forster,	117	68	345	2,530
39	Laborer, Munich, 36 years old, unmarried. Forster,	133	95	422	3,160
40	Cabinet-maker, Munich, 40 years old. Forster,	131	68	494	3,195
41	Well-paid Mechanics, Munich. Voit,	151	54	479	3,085
42	Carpenters, coopers, locksmiths, Bavaria. Average of 11 dietaries,	122	34	570	3,150
	Average of Nos. 39–42, mechanics, etc., at moderately hard work,	**134**	**63**	**491**	**3,150**
43	Farm laborers, Bavaria. Average of 5 dietaries,	137	55	542	3,295
44	Miners at severe work. Prussia. Steinheil,	133	113	634	4,195
45	Brewery laborers, Bavaria, very severe work; average of 6 dietaries,	149	61	755	4,275
46	Brickmakers, Munich (Italians); diet mainly maize, meal and cheese; severe work,	167	117	675	4,540
47	Farm laborers, Bavarian Highlands, large muscular men at severe work. Höfler,	141	202	546	4,695
48	Lumbermen, Bavarian Highlands, large, muscular, vigorous, doing heavy work in rigorous climate. Liebig and Höfler,	130	292	724	6,215
49	German army, ration, peace footing,	114	39	480	2,800
50	German army, ordinary ration, war footing,	134	58	489	3,095
51	German army, extraordinary ration, in war,	192	45	678	3,985
52	German army, extraordinary ration, Franco-German war,	157	285	331	4,650

STANDARDS FOR DAILY DIETARIES.

The ordinarily accepted standards for dietaries are estimated in terms of the three most important classes of nutritive ingredients of food, namely, protein (or albuminoids), fats, and carbohydrates. The amounts of these appropriate for daily food for different classes of people under different conditions have been estimated in two ways:

1. By observing the amounts actually consumed by individuals, and by groups of people differing in age, sex, occupation and other conditions of life. The studies of dietaries in the preceding pages belong to this class.

2. By experiments in which the income and outgo of the body are directly compared. Experiments of this sort are made by supplying individuals with food of known amount and composition and determining the quantity and composition of the products given off from the body. A comparatively simple method which has to do especially with the nitrogenous material, the so-called protein of the body and the food, consists in determining the amounts of nitrogen in the food consumed and in the excretions of the kidney and the intestines. The most valuable researches, however, are those with the respiration apparatus, as devised by Pettenkofer and improved by him, Voit and others. In these, the food, drink, and inhaled air, which make up the income and the solid and liquid excreta and exhaled air, which make up the outgo of the body, are measured, weighed and analyzed. The balance of income and expenditure is thus made, and the gain or loss of material of the body, with different kinds and amounts of food and under different conditions of muscular exercise and rest, is determined. The experiments involve a large amount of labor, but bring correspondingly complete and reliable results. They are of fundamental importance in learning the ways in which food is used in the body, and it is for this purpose that most of the respiration experiments have been made. The larger part of this kind of experimenting has been with domestic animals, only few trials have been made with men. Late improvements of the Pettenkofer apparatus make it more effective, and the time is ripe for extended and thorough experiments with men of different ages, bodily conditions and callings.

As I have repeatedly urged, collateral inquiries regarding the digestibility and the potential energy of food materials[1] and improvements of the current methods of chemical analysis[2] also, are seriously needed.

Our best information regarding dietary standards comes from Germany, where studies have been made by numerous investigators, such as Liebig and especially Voit and his followers of the Munich school of physiologists. The names of Payen in France and Playfair in England deserve especial mention as contributors to our knowledge of the subject. It is a noteworthy fact, however, that very little attention appears to have been paid in either the United States or England to the results of the latest and best research in this direction. Even the textbooks in chemistry and physiology in the English language which are looked upon as most authoritative, are too apt to pass the subject over most superficially, or almost ignore it.

Reserving detailed discussion of the subject* for another place, it will suffice to say here that from the data obtained from the two sources just mentioned, to wit, the estimates of composition of dietaries and the direct experiments, and more particularly from the former, various standards for daily dietaries have been computed. Those by Prof. Voit and the Munich school of physiological chemists are most commonly accepted and followed in estimates of dietaries.

European Dietary Standards.—The standards in table 54, compiled from European sources, are intended to represent roughly the needs of average individuals of the classes named in England and Germany. Nos. 1–8 are based upon observations of Voit and his followers. For Nos. 1 and 3, the results of numerous estimates by Dr. Kamerer of the food of his own children, and by Voit and Forster of the food consumed by a number of other children, are used. No. 2 was calculated by myself from the data of Nos. 1 and 3. The figures given represent means between smaller quantities for the younger and larger for the older children. Nos. 5 and 6 are based upon observations chiefly by Forster. Nos. 7 and 8 are by Voit, and based both upon quantities consumed by individuals under experiment, and upon observed dietaries of a much larger number of persons in Germany. No. 7 is the one so frequently quoted as Voit's standard for a "mittlerer Arbeiter," a laboring man at moderate work.* These figures represent the average needs of ordinary mechanics and laboring men at their ordinary work, as estimated from the food consumed by such men in Germany and especially in the region of Munich. For men not engaged in muscular labor, Voit regards it as better to use less carbohydrates, not over 350 grams per day, and supply the remaining need with fat. In other words, the food of well-to-do people, with intellectual rather than muscular labor, may advantageously contain more meat, butter and other animal foods rich in fat, than the largely vegetable food of the German working people supplies. Voit would have somewhat over half of the 118 grams of protein of the food of the average laboring man at moderate work, supplied by meat and other animal foods.

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[1] See Report of Storrs School Experiment Station, 1890, 174. [2] See Experiment Station Record II., 185.

* The subject is well handled in a number of German works including the following, in which references to the original investigations may be found:

Voit. *Physiologie des allgemeinen Stoffwechsels und der Ernährung.* Vol. V. of Hermann's *Handbuch der Physiologie*, 1881.

Forster. *Ernährung und Nahrungsmittel* in Vol. I. of Pettenkofer and Ziemssen's *Handbuch der Hygiene*, 1882.

König. *Chemie der menschlichen Nahrungs-und Genusmittel*, 3d edition, Vol. I., 1891.

Hammersten. *Physiologische Chemie*, 1891.

It will be borne in mind that these quantities, like those in the tables of this article, generally refer to the total rather than the digestible nutrients of the food. Such dietaries as Voit proposes would contain approximately the following amounts of digestible nutrients:

	Protein.	Fats.	Carbo-hydrates.
For laboring man at moderate work, -	116 grm.	53 grm.	450 grm.
For laboring man at hard work, - -	130 "	95 "	402 "

No. 9 is by Moleschott, whose earlier scientific life was spent in Germany, but who has lived for many years in Italy. It may therefore be called either Italian or German. No. 10 is German. Nos. 11–15 are dietaries estimated by Playfair, an Englishman, from the data cited in table 53 and others.† The figures for No. 11, subsistence diet, are based upon dietaries of reconvalescents in hospitals, of people in prison and of laboring people in England and in the so-called "cotton famine" of 1862–3, of which those of the London sewing girls and Coventry weavers, given as Nos. 1 and 2 in table 53, are examples. For No. 12, diet in quietude, the dietaries of soldiers in time of peace, and for No. 13, diet of adult in full health, army dietaries, English and Continental, in war were employed. The estimates for active laborers, No. 14, were based upon observations of the food of men at moderately active work, who would correspond in demand for nutrients to the "mittlerer Arbeiter" for which the dietaries of Voit, Moleschott and Wolff, Nos. 7, 9 and 10, were calculated. The figures of No. 15 were based upon observations of food of men in England at harder work, such as those of Nos. 7, 8 and 9 of table 54.

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* *Physiologie des Stoffwechsels und der Ernährung*, 519–523.

† *Chemical News* XI., 1865, 222.

TABLE 54.

European Standards for Daily Dietaries for People of Different Classes.

Reference Number.		Nutrients.				Potential Energy.
		Protein.	Fats.	Carbohydrates.	Total.	
		Grms.	Grms.	Grms.	Grms.	Cal.
1	Children, 1 to 2 years, average,	28	37	75	140	765
2	Children, 2 to 6 years, average,	55	40	200	295	1420
3	Children, 6 to 15 years, average,	75	43	325	443	2040
4	Aged woman, - - - -	80	50	260	390	1860
5	Aged man, - - - -	100	68	350	518	2475
6	Woman at moderate work, -	92	44	400	536	2425
7	Man at moderate work. Voit.	118	56	500	674	3055
8	Man at hard work. Voit. -	145	100	450	695	3370
9	Man at moderate work. Moleschott	130	40	550	720	3160
10	Man at moderate work. Wolff.	125	35	540	700	3030
11	Subsistence diet. Playfair. -	57	14	341	412	1760
12	Diet in quietude. Playfair. -	71	28	341	440	1950
13	Adult in full health. Playfair.	119	51	531	701	3140
14	Active laborers. Playfair. -	156	71	568	795	3630
15	Hard worked laborers. Playfair.	185	71	568	824	3750

It is hardly necessary to explain that the standards of this table represent only general averages. Thus Voit, Playfair and the other physiologists named, assume that for an ordinary laboring man, doing an ordinary amount of work, the amounts of nutrients stated in Nos. 7, 9, 10 and 14 will suffice; that with them he will hold his own, and that any considerable excess above these quantities will be superfluous. No one expects any given man to adjust his diet exactly to either of these standards. He may need more, and may perhaps get on with less. He may eat more fats and less carbohydrates, or he may consume more protein, if he is willing to pay for it. If, however, he has much less protein and keeps up his muscular exertion, he will be apt, sooner or later, to suffer.

Of course, different individuals, under like conditions, will both require and consume different quantities of nutrients. In general, the larger the person, that is to say the bulkier the machinery in his organism, the more of protein and other nutrients will be consumed. Hence men need, on the average, more than women and children. The requirements vary with the muscular activity. A man at hard work requires more nutrients than one at lighter work or at rest. Aged people, who are generally less active than those in the prime of life, require less food.

The four dietaries by Voit, Moleschott, Wolff and Playfair, just mentioned (Nos. 7, 9, 11 and 14), have long been accepted by physiologists and chemists as expressing about the average quantities of nutrients which a man doing moderately hard, muscular work would need in his food each day. They vary considerably from each other, however. That of Moleschott, for instance, calls for 130 grams of protein; that of Voit, only 118. There are similar differences in the quantities of fat and carbohydrates. But no one adjusts his food exactly to chemical standards. Different people consume very different foods, and yet they get on very well, and it is perfectly clear that either of these standards may be right enough. And different as they are, a remarkable agreement between them has lately come to light.

When these standards were proposed, experimental science had not taught how to measure the fuel value of food by the potential energy of its constituents. Late research has told how this may be done. The energy is measured in heat-units, for which Calories are here used. A gram of protein or of carbohydrates is assumed to contain 4.1, and a gram of fats 9.3 Calories. Applying this measure to these dietaries, the extreme variation in the four is only from 3,032 to 3,160 Calories. That is to say, four of the most prominent investigators, Playfair in England, and the others in Germany and Italy, working with different people and by more or less different methods, arrived at estimates which vary somewhat in the proportions of the nutrients, but when the different standards are reduced to terms of potential energy, they agree almost exactly. The closer scientific scrutiny, which the latest and most painstaking research has made practicable, serves only to bring the apparent discrepancies into accord, and thus confirm, in an unexpected and most striking way, the correctness of the standards.

To doubt the conclusions of such eminent authorities, when these conclusions are based upon such diversified experience and experiment and are substantiated in so striking a way as that just described, may seem presumptuous. I venture, nevertheless, to urge that these standards do not represent the quantities of nutritive material that the average mechanic or other working man needs in order to do a fair day's work; that the allowance is too small for what such a man ought to do and can well do. The limit of space here forbids full exposition of the considerations which seem to me to justify this assertion. I hope to discuss them more fully in another place, and meanwhile refer to some of the more essential facts in few words. They are found in the teachings of later experimental research, especially that of Voit, and others who have been associated with him, regarding the functions of food and its nutritive ingredients; and in the studies of American dietaries above described and the inferences which they seem to warrant. The kernel of the whole question is found in the fact that the European standards are based upon the food consumption of people whose plane of living is low in comparison with that of the people in the United States. The thesis which I attempt to defend is that to make the most out of a man, to bring him up to the desirable level of productive capacity, to enable him to live as a man ought to live, he must be better fed than he would be by these standards. This is only part of the story, but it is an essential part. The principle is one that reaches very deep into the philosophy of human living.

American Dietaries and Dietary Standards.—Having for our question the quantities of nutrients needful for adequate sustenance of people of different classes and conditions in life, we may begin with manual laborers. Let us take, for instance, the case of an average man—say a carpenter, blacksmith, or day-laborer—who is doing a moderate amount of muscular work. To make up for the constant wear and tear of muscle, tendon and other nitrogenous tissue, he must have protein. To use his muscles, strength, muscular energy, is required. Furthermore, his body must be kept warm. These two kinds of energy, muscular energy and heat, his body gets by transforming the potential energy of either protein, or fats, or carbohydrates. The most of the energy is supplied by the fats and carbohydrates, but some comes from protein. Our workingman, then, needs in his daily food:

(1.) Enough of protein to make up for the protein of muscle and other nitrogenous tissue consumed in his body.

(2.) Enough energy to supply the demand for heat and muscular work.

The problem, then, is this: How much protein, fats and carbohydrates does the average man, with a moderate amount of manual work to do, require in a day's food?

In a day's food for such a man the European standards just quoted provide from 118 to 130 grams of protein, and from 3,030 3,160 Calories of energy. The American dietaries cited in table 55 are much more liberal, as appears from the tabular recapitulation herewith.

TABLE 55.

Comparisons of European Dietary Standards and Dietaries for Working Men with Actual Dietaries in New England.

The numbers of the New England dietaries are those of table 49 and the numbers of the European dietaries those of table 53, in which the data are given in detail.

	PROTEIN.	POTENTIAL ENERGY.
European Dietary Standards and Dietaries.	Grams.	Calories.
Standard for man at moderate work. Voit.	118	3055
Standard for man at moderate work. Playfair.	119	3135
Standard for man at hard work. Voit.	145	3370
Standard for man at hard work. Playfair.	185	3750
Mechanics, etc., Munich, average of three dietaries, (Nos. 39–41) of persons at moderate work,	138	3150
Mechanics, Bavaria, average of eleven dietaries (No. 42) of persons at moderate work,	122	3150
Miners in Prussia (No. 44) at severe work,	133	4195
Brewery laborers in Bavaria (No. 45) at severe work,	149	4275
Brickmakers, Munich (No. 46), at severe work,	167	4540
Mechanics, etc., in Sweden (No. 13), at moderate work,	134	3435
Mechanics, etc., in Sweden (No. 14), at severe work,	189	4725
Dietaries in New England.		
Miscellaneous factory operatives, mechanics, etc., in Mass.—Average of seven dietaries (Nos. 1–7) of 421 persons at moderate work,	127	4415
French Canadian factory operatives, mechanics, etc., in Mass.—Average of seven dietaries (Nos. 13–19) of 57 persons at moderate work,	123	4620
Well paid mechanics, etc., in Conn., at ordinary work (No. 34*a*), food purchased,	126	4010
Same (No. 34*b*), food eaten,	103	3490
Machinist, Boston (No. 5), at hard work,	182	5640
Students, foot-ball team, Middletown, very active exercise (No. 40*a*), food purchased,	194	6070
Same (No. 40*b*), food eaten,	181	5740
Brickmakers, Middletown (No. 33), severe work,	222	6460
Blacksmiths, Lowell (No. 19), at hard work,	200	6905
Teamsters, marble workers, etc., Boston (No. 8), severe work,	254	7805
Brickmakers, Cambridge (No. 9), severe work,	180	8850

In comparing the figures in table 55, it should be borne in mind that neither the European nor the American figures for actual dietaries are to be taken as absolutely correct. They are for the most part estimates rather than accurate determinations. They represent, in the majority of cases, the food purchased, and make no allowance for waste, which doubtless averaged very much larger in the American than in the European dietaries. Indeed, I presume that a considerable deduction for waste, perhaps five and possibly as much as ten per cent., would have to be made from the quantities given for the American dietaries to put them on the same basis with the European. I have made no deductions for waste in the tables except where the quantities were determined, believing it better to state just what is known and no more.

On comparing the New England dietaries in table 55 with the detailed data in table 49, it will be observed that the seven dietaries of miscellaneous factory operatives, mechanics, etc., in Massachusetts, which are averaged in table 55 as those of persons at "moderate work," include one, No. 7, of a machinist at hard work. If this were excluded, the remaining six dietaries would average 118 grams of protein and 4,210 Calories of energy. In like manner the seven dietaries of French Canadian factory operatives, mechanics, etc., which are averaged together in table 49, as those of persons of "moderate work," include one, No. 19, of blacksmiths in Lowell at "hard work," omitting this, the remaining six dietaries would average 111 grams protein and 4,240 Calories of energy. But if these quantities are to be taken as representing the consumption of ordinary mechanics and laboring men at moderate work, it is a question whether the averages of the seven dietaries in each case would not be more nearly fair than that of the six, especially when they are to be compared with the people for whom the European standards were estimated. It would doubtless be hardly fair to compare the factory operatives in Massachusetts, whose dietaries are given in table 49, with those in Saxony whose dietaries are given in table 53, because the latter belonged to the poorest class of working people. At the same time, it is true that the factory work in Massachusetts has come to be done very largely by foreigners of less working capacity, receiving lower wages and living on a lower plane than ordinary native mechanics. I should suppose that the people in the cotton mills in Lowell and Lawrence would stand relatively higher in Massachusetts than the very poor operatives and laborers in Leipsic did in Saxony. But on the other hand, the Massachusetts factory operatives could hardly rank with the thrifty mechanics in Massachusetts and Connecticut, who correspond to the well paid mechanics and other wage-workers in Bavaria, from whose food consumption Voit's standards were computed. Such comparisons as these involve at best more or less of the element of statistical guesswork, and must continue to do so until we can have much more accurate and complete information, both American and European. We can only take the data now available as indications of what may be expected from a more thorough survey of the field. But believing that neither the food of the factory operatives alone, nor that of the mechanics alone, would be most justly used for comparison with the ordinary German mechanic for whom the German standards were computed, I have inserted the figures for the two groups of seven dietaries, each of operatives and mechanics in table 49 as the tentative measure of the dietaries for comparison with the European laboring men at "moderate work."

In the description of the other dietaries the terms "hard work" and "severe work" are used. The most that can be said of these is that they indicate work requiring more muscular exertion than what is called "ordinary" work. For the exact amount of the exertion we have no accurate measure. To get such a measure, experiments with specially devised apparatus would be necessary. I have no doubt that such experiments would be feasible. The trouble is that they would be expensive.

Taking the data as we have them, I have attempted to arrange the dietaries, both American and European, in three tables 55, 56 and 57, somewhat in order of the muscular exertion as indicated by the descriptions. In the American descriptions, the term "severe work" is used to imply more strenuous labor than "hard work." In the German descriptions, including those of the Swedish dietaries which were reported in Germany, the term "angestrengte Arbeit" is the most common for work involving strenuous muscular exercise, and is here translated as "severe."

The dietaries of the lumbermen in the Bavarian highlands of table 51 are not included in the comparison because they are exceptional. All of the others, of both American and European, except the farm laborer and some of those of French Canadians in Canada, represent the food of people in towns. If we could have estimates of food of the lumbermen in Maine or Michigan, who, like those in the Bavarian mountains, are engaged in strenuous, muscular exertion in the open air and in a rigorous climate and who are likewise reputed to consume large quantities of food and especially of fatty foods, the two might be appropriately compared.

The dietaries of the French Canadian families in Massachusetts, Nos. 10, 11 and 12 of table 49, whose fathers were brickmakers at severe work, are also omitted from the comparisons in table 55. The quantities of protein in these dietaries were relatively small, and the potential energy, though averaging larger than those of any of the German dietaries outside of the Bavarian mountains, is less than that of any of the other New England dietaries of men at hard or severe work. There are two reasons for not including these in the comparison. One, which would also apply to other French Canadians in Massachusetts, is that the people are not natives and bring more or less of their eating habits with them. The other, which is more to the point, is that the method by which the amounts are calculated per man per day is hardly just in such cases, as these in which only one member of the family is engaged in severe work. As above explained, these calculations assume that if the amount of food consumed by a man at ordinary work be taken at ten, that of woman in like circumstances may be taken at eight and that of children at correspondingly lower figures. In cases like these where the family consists of father, mother and a number of children, and the father alone is engaged in strenuous, muscular exertion, the estimate for his proportion of food should theoretically be much larger. Rather than to attempt an accurate estimate with so insufficient data, I have chosen to omit these dietaries from the comparison. In the same way, some of the other American estimates of nutrients and energy in the food of men at hard and severe work may be too low, but the error is on the safe side, that is, it makes such dietaries appear smaller rather than larger than they are.

Two facts are brought out very clearly by the comparisons here made:

First—The increase in the demand for food which comes with increase of muscular exertion. This, though understood, is not generally appreciated.

Second—The larger quantities of food consumed by working people in New England as compared with people in corresponding conditions of life in Europe.

To these there is another consideration to be added, though the statistics of production do not yet suffice for its exact numerical expression. It is that the better fed wage-workers in Massachusetts and Connecticut do more work than those with like callings but inferior nourishment in Saxony and Bavaria.

It would be going too far to assume that the figures of the tables of dietaries above are exact measures of the food consumption in either of these four localities. It would be still less justifiable to claim that the New England dietaries here estimated represent accurately the average food consumption for working people in the whole United States, or that the German dietaries cited are typical for wage-workers throughout Europe. I cannot, however, avoid the impression that, in so far as the figures fail to represent the average facts on the two sides of the Atlantic, the American data come fully as near, if not nearer, to the average conditions in the United States than the German ones do to the conditions in central and western Europe, for we have not in the United States the large numbers of the under-fed poor, who are so numerous among the working classes there, and of whose dietaries examples are given in the summary of European dietaries, table 53, but are excluded from the comparisons in table 55. In other words, while I have found no reason to think that the people in New England, whose dietaries are set forth in the tables, are better fed than the average people of their occupations elsewhere in the United States, there does seem to me to be good reason to doubt whether factory operatives, mechanics and other wage-workers in general on the continent of Europe, have as abundant and nutritious food as the standard dietaries of Voit and others call for.

This impression has been deepened by such observations as I have had opportunity to make in the several regions named. It has been my fortune to pass considerable time in different parts of Germany, including the cities of Munich and Leipsic in which the studies here referred to were made, and not only to see more or less of the people, but converse with not a few of the best known students of the subject. To one accustomed to the plentiful nourishment of laboring people of small incomes in the United States, there is something pathetic in the frequency with which such expressions as *Mangel an Lebensmittel* and

Hungersnoth, which indicate the lack of food and positive want, are used by statisticians, economists and others interested in the welfare of the poorer classes of wage workers, in discussing their condition. Within a short time past, I have had occasion to learn somewhat more than before of the condition of wage-workers in Saxony, and have been surprised and pained anew by the condition in which they live and work. The scantily-fed, those who live upon the nutritive plane expressed in the smaller European dietaries (Nos. 15–25 of table 53), with from only 50 to 80 grams of protein, and from 1,800 to 2,800 Calories of energy, are sadly numerous. Large bodies of the most industriously disposed working people in the cities and in the country, including many operatives in manufacturing establishments whose products are exported to the United States, live in what to us would seem almost the borderland of starvation.

Impressions must, of course, be taken for what they are worth, but I cannot see how any one, who takes the trouble to look into the matter at all, could well have any other opinion than that which I have ventured to express regarding the relative condition of the laboring classes in the two countries.

The men at "moderate" and "severe" work, upon the observation of whose food consumption Voit's dietaries were based, lived upon a higher nutritive level than many of their fellow wage-workers, but it would be a low level for even such people as factory operatives with us.

The facts and considerations thus set forth have led me, rightly or wrongly, to the following very definite conclusions:

1. The statistics of food consumption upon which the dietary standards of Voit and others above quoted for laboring at "moderate work" represent a standard of living decidedly lower than that with which we are fortunately familiar in the United States. Unquestionably, we eat a great deal more than we need, but it would be very hard to believe that food with 3,055 Calories of potential energy per day, which Voit's standard for a man of moderate muscular work calls for, would suffice for men who live and work and earn wages as do the laboring people in Massachusetts and Connecticut, the heat and strength-giving energy of whose food, including that which is so lavishly wasted, is estimated at from 4,400 to 4,660 Calories per day.

2. A dietary for the average American wage-worker doing what would count as "moderate work" must be nearer that which the

European standards above quoted require for a man at "hard" or "severe" work. In table 57, beyond, I have assumed 125 grams of protein and 3,500 Calories of energy as appropriate for a man at moderate muscular work.

Further statements in this especial line will come more appropriately in connection with what is to be said later regarding the food of American and European working men and the work they do.

The data of tables 55 and 56 throw some light upon the demands of people of more sedentary habits, especially such as are engaged in intellectual rather than muscular labor. Regarding the adaptation of food to the mental and nervous organization, or the demands for brain work as distinguished from muscular activity, the physiological chemistry of to-day has very little to say; it accepts the hygienic doctrine that mental health and vigor are promoted by health and vigor of the body. There are indeed very few statistical observations on record of the food consumption of professional men, so far as I can find. Those in table 56 are, however, instructive.

TABLE 56.

Dietaries of Professional Men.

			PROTEIN.	POTENTIAL ENERGY.
			Grams.	Calories.
European.				
University professor, Munich,			100	2325
Lawyer, Munich,			80	2400
University professor, Marburg,			94	2570
Physician, Munich,			134	2695
Physician, Munich,			127	2830
Physician, Copenhagen,			135	2835
Students, Stockholm, av'ge of 5 dietaries of 5 persons,			127	3035
Average of European above,			114	2670
American—Middletown, Conn.				
Chemists,			118	3205
College professor,		food purchased,	129	4145
		food eaten,	128	4080
Students, N—— Club,		food purchased,	141	4130
		food eaten,	140	4105
Students, M— Club,	first dietary,	food purchased,	161	5345
		food eaten,	138	4825
	second dietary,	food purchased,	115	3875
		food eaten,	104	3415
Average of American above,		food purchased,	133	4140
		food eaten,	126	3925

The dietaries of Professors Ranke and Beneke of the German Universities of Munich and Marburg were studied by these gentlemen themselves, with especial care and accuracy, for the purpose of finding what proportions of nutrients were needed. There was no restriction upon their diet; the attempt was to make the food in each case conform to the actual demands. The Munich lawyer and physician were selected by Prof. Forster as individuals typical of their classes. The dietary of the Danish physician studied by Dr. Jürgensen belongs to the same category of professional men with only light, physical exercise and considerable mental work. The Stockholm students worked several hours per day in the laboratory, so that their occupation partook somewhat of the character of that of mechanics at light muscular labor.

The order of the dietaries in respect to amounts is interesting. Of the men engaged in professional duties, the professors and the lawyers, who would be presumed to have the least muscular exercise, consumed the least food. The physicians who, in the daily practice of their profession, would be expected to exercise more, consumed more. The people in Munich consumed the least, and those in the more northerly and colder latitudes of Denmark and Sweden, the most. This coincidence between lighter muscular labor, warmer climate and smaller food consumption on the one hand and more active physical exercise, colder climate and larger food consumption may be more or less apparent rather than real, and that which is real may be largely accidental, but the coincidence is at least worth noting.

The important fact for our present purpose is this: Here are a considerable number of men in comfortable circumstances, able to provide themselves with ample food, and living in circumstances which would seem to favor proper nutrition. Their food contains from 80 to 135 grams of protein, and from 2,325 to 3,035 Calories of energy per day. The dietaries average 114 grams of protein and 2,670 Calories of energy. For the active study or professional practice in which they are engaged, their nutriment is ample.

Let us now compare with these the dietaries of the professional men and students in Connecticut, taking for the latter the food actually consumed. The protein in the American dietaries averages about 10 per cent., and the fuel value very nearly 50 per cent. more than in the others. The range of protein is from

104 to 140, and averages 126 grams. The range of fuel value is from 3,205 to 4,825 and averages 4,140 Calories.

Was there any need of so much larger food consumption in Middletown than in Munich, Copenhagen and Stockholm? Did the professor and chemists in Connecticut require so much nutriment when professors and physicians in Bavaria and Prussia are well nourished with so much less? Did the students in Wesleyan University, who are mostly from the northern and eastern states, need so much more protein and energy than the presumably Swedish students in Stockholm? It seems to me very decidedly not.

The lower nutritive standard of the European, as compared with the American, wage worker coincides with his smaller income, which forbids generous diet, and his smaller capacity for work. But these European professional men and students were able to eat all they needed, and I fear it would be difficult to prove that the intellectual activity of the American men of like calling was so much greater as to call for so great an excess of protein and energy in their food.

Doubtless we live and work more intensely than people do in Europe. We also take more out-of-door exercise. Students with us are fortunately much more given to athletic exercise than are German students. How it was with the medical students in Stockholm in this respect, I do not know. Possibly they may have been so much more active physically than the young physicians in Munich and the other professional men in Germany as to need the ampler diet which they enjoyed. And it may very well be that the gentlemen in Connecticut used their muscles more and lived at higher tension than those on the other side of the Atlantic, and on these accounts needed more nutriment. But it is hard to see how they could have required food with a fifty per cent. higher fuel value.

The Middletown professor, with his 128 grams of protein and over four thousand Calories of energy per day, was engaged in almost precisely the same kind of labor as his fellow craftsmen in the German Universities, who were able to accomplish most excellent work and a large amount of it with 97 grams of protein and about 2,450 Calories of energy. Was his diet fitted to his actual needs, or was he consuming a large excess of food, and that to the detriment of his health, not to say his purse?

Precisely this question occurred to him when he learned the result of the examination of his dietary. He had supposed himself to be what is styled in common phrase a "small eater," and the magnitude of his food consumption was a great surprise. Thereafter he tried the experiment of reducing the quantity of his food, especially the carbohydrates and fats. According to his estimate, roughly made for his own satisfaction, the protein of his food was diminished by at least one-fourth or one-fifth and the energy by perhaps a third, so that, if his guess was correct, his daily consumption approached closely to that of the Marburg professor, or the Munich professor or lawyer. He found himself in no way inconvenienced, but, so far as he could judge, decidedly better in health and strength on the smaller diet, and after a time such quantities of food as he had been formerly accustomed to consume were positively distasteful.

The dietary of the two chemists is the smallest of the American dietaries examined. They were large, heavy men, one had been a noted athlete in college, both were active tennis players and both more than usually industrious in their studies and their laboratory work. They were especially interested in dietary investigations and, weighing their food daily, it would seem natural that they should avoid great excess. This I surmise to be the real explanation of the smallness of the dietary. It corresponds almost exactly with Voit's standard for a laboring man at moderate muscular work.

The case of the students of the M—— Club is decidedly interesting. The steward who provided the food of the first dietary was a large, vigorous young man from Maine, accustomed to hard work and liberal food with large quantities of meat, especially of the fatter sorts. The protein consumed was 138 grams, the energy was 4,825 Calories; even more than in the extraordinary ration provided for German soldiers in the trying marches and fierce fighting of the Franco-German war. The second dietary was under the management of another steward, who was personally less fond of the fatter meats and had learned the outcome of the examination of the first. The protein was reduced to 104 grams and the energy to 3,415 Calories. The members of the club, according to his account, so far from objecting to the change, hardly noticed it.

Suggestions for Dietary Standards.

In table 57, I venture to suggest certain proportions of protein and energy which may be appropriate as averages for dietaries for people of different forms of activity. In the method by which the estimates are made, these agree with those of Voit and Playfair in that the proportions assumed to be needed are inferred empirically from those consumed in observed cases. They differ from the ones referred to in the use of the experience that has accumulated during the not far from two decades since the latest of the latter, those of Voit, were proposed; a period of no little activity of research in the science of nutrition. But the principal reason for the wide differences in the quantities is that the results of the inquiries regarding American dietaries have been taken into account in the estimates here given.

Concerning the quantities of protein, it must be confessed that the experimental data do not yet suffice for at all exact estimates even for average persons of different classes. The proportions here given are such as seem to me reasonable in the light of the present knowledge. The same may be said regarding the figures for energy.

The estimates in table 57 are expressed simply in terms of protein and energy. There is really little ground for giving quantities of fats and carbohydrates in such standards, since the two are mutually replaceable, and the quantities must vary with the conditions of consumption.

Regarding the standards of table 57, a few additional remarks will suffice.

It will be observed that the quantities are in a well-nigh regularly ascending scale. The lowest are such as have been found to suffice amply for men of sedentary life. The highest accord with the larger, but not the largest, of the American dietaries quoted in table 49. The quantities in No. 1 are about the same as were found ample for the German professors and lawyer above referred to, who were men of decided mental activity. They might be small for the average man of like occupation with us, in which case such proportions as those of No. 2 would be more appropriate. The standard for a man at moderate work, which Voit places at 118 grams of protein and 3,050 Calories, and Playfair and other authorities at very nearly the same figures, I have placed at 125 grams of protein and 3,500 of energy. These are smaller than the averages of the American dietaries, but I have assumed that the waste in the latter would count for considerable and that the quantities actually eaten would not be so very far above these figures, particularly as the allowance here for a man at active muscular work is 150 grams of protein and 4,000 Calories of energy.

It has been assumed a woman requires on the average eight-tenths as much as a man for corresponding muscular activity. I have assigned the dietary of a man with light exercise to a woman at moderate work, and that of a man with very little physical exercise to a woman at light work, thus providing for a woman rather more than eight-tenths as much as a man. Very likely eight-tenths would accord more nearly with the actual needs.

It is quite possible that the quantities of non-nitrogenous nutrients necessary to furnish the energy called for in the following standards would be large in comparison with the amounts of protein; in other words, that the nutritive ratios are too wide for normal nutrition. In this respect they are a compromise between the currently accepted European standards and the actual dietaries observed in New England.

TABLE 57.

Standards for Daily Dietaries of Adults.

No.		PROTEIN.	POTENTIAL ENERGY.
		Grams.	Calories.
1	Man with very little physical exercise, or woman with light work, - - - -	90	2500
2	Man with light, or woman at moderate work,	100	3000
3	Man at moderate muscular work, - - - -	125	3500
4	Man at active muscular work, - - - -	150	4000
5	Man at severe muscular work, - - -	175	5700
6	Man at very severe muscular work, - -	200	7500

METHODS OF FOOD INVESTIGATION.

BY W. O. ATWATER.

Whatever may be the value or the lack of value of the investigations here reported, they are useful in indicating what needs to be done in this direction. At present, research is especially called for in four directions.

Improvements of Methods of Chemical Study. — Our present methods of analysis of foods and feeding stuffs do not distinguish accurately enough between the different ingredients, nor do they, as now applied, suffice to show with the needed clearness the constitution of the several ingredients and classes of ingredients. Special attention has been called of late to the need of improving our methods of chemical study of feeding stuffs for domestic animals.* The same principles apply to the investigations of the food of man.

One of the topics that just now demand attention is the nature of the compounds which occur in muscular tissue. Studies in this latter direction have been made in connection with the investigations above reported.

Calorimetric Investigations.—Late experimental research is bringing us to the point where we can make use of the heats of combustion of the nutrients of foods as a measure of their fuel value. This is a notable advance, but the data now available are very far from complete. Unfortunately, this topic has not received the attention its importance calls for. Several chemists in Germany, France and elsewhere in Europe are doing most excellent work, but it requires the united labor of a much larger number.

Accounts of calorimetric investigations made in connection with the studies of foods above detailed, were given in the report of the Storrs School Experiment Station for 1890.

Studies of the Digestibility of Foods.—Here again we are dependent almost entirely upon what is done in Europe for our information. In the physiological laboratories of a number of universities, mostly German, a considerable amount of experimental inquiry upon the digestion of food by men is being prosecuted. The experiment stations in Europe and, of late, in the United States also, are doing a great deal in the study of the digestion of feeding stuffs by domestic animals, and the methods of testing the digestibility of these materials by artificial means are being gradually elaborated. It may be expected that these latter will come to be applicable to the testing of the digestibility of materials used as food by man.

Studies of the Functions of Food in Nutrition.—To know exactly how the different ingredients of foods do their work in nutrition, and what are the demands of different persons and classes of persons, requires exact determinations of the income and outgo of the body. For these the respiration apparatus is essential. This apparatus is complicated and costly, and the experiments are laborious and time-consuming. In consequence, but few have been made. More are urgently needed.

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* Experiment Station Record, II., 184.

The conditions of our modern life are such as to make inquiries regarding the nutrition of people, whose work is intellectual rather than muscular, more and more pressingly needed. Satisfactory results will require a great deal of labor, but once obtained they would be a benefaction to a large class of society.

Research of this kind culminates in the study of the income and expenditure of energy by the body. Thus far no entirely satisfactory method has been made known for the settlement of the perplexing questions which open up in this particular direction, but the advances toward it are very rapid.

Investigations of Dietaries.—Both the usefulness and the deficiencies of dietary investigations are brought out by the observations and discussions of the two preceding chapters. The trouble with the majority of the dietary investigations on record is that they are not accurate enough. To give them the needed accuracy, a great deal of careful detail is necessary; more than can generally be devoted to the work.

The investigation of the dietary of a boarding-house in Middletown by Mr. Woods is by far the most thorough piece of work in this direction thus far done, to my knowledge, in the United States. More studies of the same kind are wanted and will, I trust, be provided.

It is desirable that observations of the quantities of food actually digested and of the protein metabolism accompany the determinations of the accounts and composition of the food actually consumed.

Investigation of Food as Related to Production and Wages.—In the comparisons of the food of American and European wage-workers in the previous chapter, reference is made to the connection between food consumed, work done, and wages received. The beginnings of a research in this especial direction have been provided for in connection with the U. S. Department of Labor.

Food Investigation in its Relation to Agriculture.—The importance of this kind of inquiry for our farming interests is briefly set forth in the succeeding chapter.

ECONOMIC APPLICATION OF RESULTS OF STUDIES OF FOOD AND DIETARIES.

The purpose of the preceding account of the results of the studies of foods and dietaries is to make a permanent record of the details for reference, and to explain some of the ways in which information may be made useful. Some of the more important practical conclusions, with explanations regarding the nutritive values of our ordinary food materials, and the pecuniary as well as the hygienic economy of their use, were given in Bulletin No. 7 of the Storrs School Experiment Station. Partly from lack of space here and partly because it is hoped that further results of general interest may be obtained, it has not seemed advisable to discuss the practical results in full in the present report. A brief statement of some of the conclusions, including several which were not dwelt upon in the Bulletin referred to, may, however, not be out of place.

Food constitutes the chief item of the living expenses of the people and of our agricultural production, and one of the most important of our exports to Europe.

Wage-workers and people of moderate incomes generally in New England spend and must spend nearly half their earnings for food. Although "half the struggle for life is a struggle for food," and although the health and strength of all are so intimately connected with and dependent upon their diet, yet even the most intelligent people know less of the actual uses and values of their food for fulfilling its purposes than of those of almost any other of the necessities of life.

The lack of information regarding the nutritive values and proper uses of food results in great waste in the purchase and use of food, loss of money, and injury to health.

The waste in the purchase and use of food is illustrated in the statistics cited and discussed on pages 96–99, 126–130, and 142–159, and in Bulletin No. 7 of the Station, above referred to.

We make a three-fold mistake in our food economy. First, we purchase needlessly expensive kinds of food. The cheapest food is that which supplies the most nutriment for the least money. The most economical food is that which is the cheapest and at the same time the best adapted to the wants of the user. The maxim that "the best is the cheapest," does not apply to food. The best food, in the sense of that which is the finest in appearance and flavor, and which is sold at the highest price, is not generally the cheapest, nor is it always the most healthful or economical.

Even among those who desire to economize, there is great pecuniary loss from the selection of materials in which the actual nutrients are really, though not apparently, dearer than need be. Many whose means are limited make serious mistakes in their choice of food, so that they are often inadequately nourished when they might be well fed at less cost; and, what is the most painful thing of all, it is generally the very poor who practice the worst economy in the purchase as well as in the use of their food. Here as elsewhere it is true that "to him that hath shall be given, but from him that hath not shall be taken away even that which he hath."

Second, the food which we eat does not always contain the proper proportions of the different kinds of nutritive ingredients. The proper adjusting of food to the wants of the body is a balancing of income and outgo. The body has certain necessary expenditures, and to maintain it in health it must have income to meet them. The diet should provide an income corresponding to the needed expenditure. We consume fats and carbohydrates in relative excess.

On pages 142–3 are comparisons of European and American dietaries, and on pages 147 and 161 dietary standards are given. It is there urged, and more detailed consideration will bring additional support to the view, that the relative proportions of nutrients in the dietaries of well nourished people in Europe and in the dietary standards, are better fitted to the natural demands for nourishment than those in the food of which the American dietaries are made up.

The quantities of fat in the European dietaries range from 1 to 5 ounces per day, while in the American the range is from 4 to 16 ounces. In the daily food of the well-to-do professional men in Germany, who were amply nourished, the quantity of fat is from 3 to 4½ ounces. The quantities of carbohydrates in the European dietaries range from 9 to 24 ounces, while in corresponding American dietaries they were from 24 to 60 ounces. People in this country eat what is set before them, asking no questions for economy's sake, provided it suits their taste. We are a generation of fat and sugar eaters. We are so because of the abundance and toothsomeness of foods containing fat and sugar.

Third, in this country many people (not only the well-to-do, but those in moderate circumstances also,) use a needless quantity of food; part of this excess, however, is simply thrown away, so that the injury to health, great as it may be, is doubtless much less than if all were eaten. The figures above referred to confirm most emphatically the general impression that we consume much more food than is required for our best nourishment.

It would be rather hazardous to affirm that men at severe muscular work do not need as much as even the amounts supplied in the largest of the American dietaries cited. But if the generally accepted belief of physiologists is correct, the quantities of nutrients stated in the dietaries of people with moderate and light physical exercise, are far in excess of the average needs.

One striking confirmation of the excess of food in our dietaries is in the amounts thrown away, as illustrated in the cases cited on pages 97–9 and 127–8. It would be an interesting study in social statistics for any one willing to undertake it, to find out how much of the food which the different classes of people in this country pay for is thus wasted. Without doubt a very considerable proportion of fat in the American dietaries here examined should be deducted in order to get at the amounts actually eaten. If any one doubts this, let him observe how much fat of meat is left with the butcher, and how much of that which is cooked and served upon the table is left on the plates, to be sold to the soap-man or thrown into the garbage.

It may be urged that people in our Northern States need a larger amount of fuel in their food on account of our rigorous winters. To this there are three objections. In the first place, the actual difference in temperature between those regions for which the European estimates are made and the northern United States is not great. Secondly, even if our winters are slightly colder, we spend our time in well-warmed houses and are warmly clad, so that the actual difference in exposure is far less than the difference in temperature. And, finally, the difference in demand for food-fuel for warming the body in regions of different temperatures is not so large as is often supposed.

The American dietaries here reported contain much larger proportions of fuel materials, fats, and carbohydrates than the best evidence implies to be appropriate. This is manifested in the large quantities of fat and sugar and in the wide nutritive ratios. Allowing that the food consumption, of which statistics are here exhibited, is approximately representative of that of people in the United States generally, we are led to the conclusion that:

Our national dietary has become one-sided, so that, although we live upon a high nutritive plane, our food might be better fitted to our needs. The chief error seems to be in the use of needless quantities of the fatter kinds of meat and sweet-meats.

The subject is an important one for the wage-workers. Statistics, as well as common observations, bear emphatic testimony to the better condition of the American as compared with the European workingman, in respect to his supply of the necessaries and comforts of life. Nowhere is this superiority more striking than in the quality and quantity of the food. The difference in the dietaries of the two is especially marked in the larger amounts of protein, which forms the muscle and other parts of the framework of the body, and of potential energy of capability to yield muscular strength for work, which characterizes the food of the American.

The exact statistics of food consumption of laboring people in the United States and in Europe are very limited. Extended studies will be needed to justify numerical statements of comparative amounts consumed. If the data now available are to be taken as representative, the inference will be that the daily food of mechanics and kindred wage-workers in the eastern, if not in the whole United States, is not only the larger in quantity, but also the more nutritive in quality, because of the larger quantities of meat, fish, milk, and other animal foods; that in amount of material for building muscle and other tissue, and for supplying heat and muscular strength, it exceeds that of people of corresponding occupation on the continent of Europe by at least one-third, and perhaps one-half.

The American workingman is better paid, better housed, better clothed, and better fed than the European. He has better opportunities for self-development, more to stimulate his ambition, and more hope of reward if his work is efficient. He accomplishes a great deal more. That this superiority is due to more nutritious food, as well as to greater intelligence, is hardly to be questioned.

But the better nourishment of the American wage-worker is largely due to our abundant food production. With the growth of population, and the increasing closeness of home and international competition, his own diet cannot be kept up to its present nutritive standard, nor can that of his poorer neighbor and his foreign brother be brought up to that standard, without better knowledge and application of the laws of food economy.

The significance of this subject is more than national. It has a profound international importance. Our agricultural production exceeds, while that in Europe falls short, of the home requirement. With us, many people consume more food than they need; there a large part of the population is underfed. Here working people do large work and earn large wages; there they do less and are very poorly paid. Here are a high standard of material comfort, ambition, hope, and constant progress; there are a lower plane of living, less hope, less ambition, and less rapid progress. Viewed from this standpoint, nothing could be more unwise on the part of European governments than the restrictions they place, by high duties and otherwise, upon the importation of American food products.

To the farmer this subject is of vital interest. The agricultural production of the United States is out of balance. Our food supply for man and beast contains an excess of the materials which serve the body for fuel, and are relatively deficient in the nitrogenous compounds which make blood, muscle, and bone.

In other words, the farmer produces relatively too much starch, sugar, and other carbohydrates; too much fat and too little protein. The crops he grows are, taken together, deficient in protein, and the meat he makes is excessively fat. The one-sidedness of our food-consumption is the natural result of the one-sidedness of our food-production.

This one-sidedness of our agricultural production is easily explained. In the first place, our vegetable products are deficient in protein. Corn, our great staple, is poor in protein at best. From careless culture, insufficient manuring, or other reasons, our grasses, grains, and other crops contain much lower proportions of nitrogen then they ought to, and much less than the same ones do in Europe, where farming is more thoroughly done.

It looks very much as though we have, by careless culture and insufficient manuring of our grasses and other forage crops, if not our grains, for years been gradually breeding varieties poor in nitrogen, while our transatlantic brethren have been pursuing the opposite course. Certain it is that our grasses often contain smaller percentages of protein than are found in the best qualities of cornstalks and even straw.

In the second place, our meats, upon which we depend to supply the protein which our vegetable foods lack, are excessively fat. The analyses of meats on pages 59–81 illustrate their fatness. The rejection of the fat of meats in the butchers' shops and the demand for leaner meats in the markets are the instinctive protests of the public against an excess which nature disapproves.

This excessive production of fat in meat is uneconomical in several ways. A large amount of vegetable material is required to make a small amount of fat, the protein is lost in the process, and the fat thus produced is sold in a food market where it comes in competition with other materials of which there is a relative overproduction.

The fat of meat, lard, butter, cotton-seed oil, and sugar and starch, which constitute the larger part of the nutritive material of wheat and other grains and nearly the whole of that of potatoes, all do the same work in nutrition; they are the fuel of the body. Taking our food production and the demand of the country for nutriment, each as a whole, we have a large excess of the materials which serve as fuel, while the protein compounds, which build muscle, tendon, bone, and other tissues, are relatively deficient. And the case is made still worse for the producers of these fuel materials by the abundance and cheapness of petroleum, which now serves for illuminating and lubricating purposes where tallow, lard, and other animal oils and fats were once employed.

The cattle grower, the pork producer, the dairyman, the sugar maker, the raiser of wheat and potatoes, and the cotton planter, are engaged in an unwitting, but none the less severe, competition with each other in supplying the food market with fuel materials, with which it is relatively overstocked, and are, all together, competing with petroleum.

The one-sidedness of our dietary is the result of this one-sidedness of our agricultural production. As the farmer is primarily responsible for this state of affairs, and the first loser by it, so he must be the one to take the first steps to amend it. The remedy for the evil is in growing crops with more protein. The needed increase of protein may be obtained by breeding and importing varieties of grains and grasses richer in nitrogen than those we now cultivate, and by *growing more legumes, such as clovers, alfalfa, vetch, seradella, cow peas, peas, and beans.*

The value of nitrogenous feeding stuffs is not sufficiently appreciated, but the progress of exact experiment is bringing it out more and more clearly. Thus the experiments of the effects of fodder upon the production of milk lately made in some of our stations, emphasize most forcibly the need of rations much richer in protein than most farmers feed. Similar and still more striking results have been found in an extended series of experiments on feeding of cows for milk and steers for fattening, conducted with great patience and thoroughness on a number of farms in Prussia, under the auspices of the Halle Experiment Station. Even with the good quality of the coarse foods, hay, clover, and straw, there grown and fed, very large proportions of concentrated nitrogenous foods were found advantageous. More protein and narrower rations than those of the German feeding standards (of Wolff) so often quoted, were found most profitable.

The advantage of good manuring and culture, to bring crops rich in protein, is illustrated in the account of experiments with grass, on page 29 of the present Report. The advantages of leguminous plants are insisted upon in a preceding article, page 9, and were summarized as follows, in Bulletin No. 6 of the Station:

The legumes are especially valuable because of:—

1. Their large percentages of protein compounds which serve to form blood, muscle, bone, and milk, and their consequent feeding value, which exceeds that of the grasses, corn fodder, corn stover, or straws. They may be used to supplement these fodders in place of the concentrated nitrogenous feeds, such as bran, cotton seed, linseed, and gluten meals, etc. Hay from the legumes is twice or more than twice as rich in protein as that from the grasses.

2. Their power of gathering large quantities of plant food from natural sources. Many, if not all, of our common legumes acquire considerable quantities of nitrogen from the air. Their roots penetrate deeply into the subsoil, and they thus obtain plant food from depths beyond the reach of plants with smaller root development.

3. Their manurial value. When the crop is fed, most of the nitrogen, phosphoric acid, potash, and other fertilizing ingredients go into the excrement, liquid and solid, and if preserved, make a rich manure. If the crop is plowed under, its plant food, including that acquired from the air and gathered from the subsoil, becomes available for succeeding crops. The large amounts of plant food left behind in roots and stubble after the removal of the crop, furnish a cheap and valuable store of plant food for following crops.

While the clovers will doubtless prove in the future, as they have in the past, the most valuable of the legumes for general purposes in Connecticut, the cow pea, soja pea, and vetches are valuable for forage, silage or hay, and the experiments and observations at the Station and elsewhere indicate that they are worthy of careful trial.

The legumes do not require nitrogen in manure, but do well with the less expensive mineral fertilizers. They obtain nitrogen directly from the air and convert it into protein. The farmer needs this protein for fodder; by mixing the leguminous products with poor hay, straw, and cornstalks, which lack protein, the latter can be most profitably utilized. The food thus produced for stock is what is needed to make leaner meat and more of it, and more milk at less cost; the nitrogen not transformed into meat or milk makes rich manure for grasses, grains, and other crops; and finally, the richer manure helps to bring larger crops and crops richer in protein.

The error which causes the one-sidedness of our agricultural production brings cumulative ill; the means for amending it will bring cumulative good.

A reform in our agricultural production and in our diet must come, but it will come no faster than our farmers learn to produce crops richer in nitrogen, and to make more meat and leaner meat from less vegetable material; and consumers learn to buy and use meats and other foods of the kinds and in the proportions best suited to their actual needs. The agricultural reform will lead to the production of more food from less land. The dietary reform will result in the eating of less food per person, and food better adapted to the demands of health, work, and purse.

BACTERIA IN THE DAIRY.

BY H. W. CONN, PH. D.

During the last year the investigations upon bacteria in the dairy, described in previous reports of the Station, have been continued; but the results are not yet ready for publication. Two series of experiments have been undertaken. The first series have been upon artificial ripening of cream by means of pure cultures of bacteria. These have been accompanied by a study of the butter made from such artificially ripened cream. They have been carried on in connection with the dairy of the Station and with the help of Prof. Phelps and Mr. Bailey. The flavor of the butter varies widely with the species of bacteria used in ripening the cream. In some cases very disagreeable smelling and tasting butter was obtained from the artificially ripened cream, while the control trials gave a good quality of butter. In other experiments there was very little difference in the quality of the butter obtained in the two cases, and in one or two instances the butter obtained from the artificially ripened cream was noticeably superior in its flavor to that obtained from the normally ripened cream.

The second series of experiments that have been conducted have been for the purpose of getting light upon the question whether the dairies of this country are under the influence of the same set of species of bacteria as the dairies of Europe. For several years I have been on the lookout in my laboratory for the *Bacillus acidi lactici* of Hueppe. This species of bacterium has been described as specially abundant in the dairies of Europe. But while many species of organisms have been isolated from milk in my laboratory, some of which were extremely numerous, no indication has been found of a species which agreed with the organism of Hueppe. Several distinct species of organisms have been found very abundant in souring milk, which certainly sour it in a normal manner, but we have been forced to conclude, as a result of experiments thus far, that the lactic organism described byHueppe is at all events not common in the vicinity of Middletown.

CO-OPERATIVE FIELD EXPERIMENTS WITH FERTILIZERS.

BY C. S. PHELPS.

The Station has continued its coöperative field experiments through a fourth year, the plan being essentially the same as that adopted in the spring of 1888. The experiments have been of three classes: "Soil Tests," "Special Nitrogen Experiments," and a third class designated as "Special Corn Experiments." The last were planned for the purpose of studying the most profitable mixtures for use on farms where a soil test had already indicated some of the peculiarities of the soil.

The details of the experiments were largely under the supervision of Mr. Bailey, the Assistant Agriculturist. Much of the success of the work is due to the care and accuracy exercised in all matters entrusted to his care.

The object of the experiments may be stated briefly as follows:

1. To work directly upon farm lands in different parts of the State, and to aid the owners in learning the deficiencies of their soils and the requirements of their crops.

2. To help farmers in becoming familiar with the forms and action of fertilizing materials containing phosphoric acid, potash, and nitrogen, and to better understand their profitable use.

3. To encourage a spirit of investigation; and thus to gradually develop a number of farm experimenters, whose work will be useful not only to themselves, but in a larger degree to their communities and to the agriculture of the State.

The general plan and scope of the work is discussed only briefly in this Report, the following pages being occupied mainly with a discussion of the results obtained during the year 1891. Directions for the experiments will be found in Bulletin 1 and its supplement, and in the Second Annual Report of the Station.* The reader is referred to these for a detailed plan of the work, and for information that would aid in carrying out the experiments.

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* Pages 91–106.

Besides the work done at the Station, the following persons have coöperated in this line of experimenting, during the past year:

	POST OFFICE.
M. H. Dean,	Falls Village.
R. S. Hinman,	Stevenson.
K. B. Loomis,	South Manchester.
H. W. Sadd & Son,	Wapping.
Clinton Peck,	Franklin.
J. H. Tucker,	Lebanon.
F. L. Ensworth,	Canterbury.
Jerome Warren,	Putnam.

In connection with nearly all of these experiments, rainfall records have been kept during the growing season. These, as a rule, have been made in close proximity to the experimental fields. The importance of records near at hand is shown by the differences in rainfall between places but a few miles apart. On pages 15 and 16 of the report will be found the meteorological summary, and the rainfall for the growing season for twenty localities in the State.

MOISTURE TESTS OF CORN.

Pounds Required for a Bushel of Dry Shelled Corn.

The percentages of water in the crop from different fields are found to vary widely. The field weights are not an exact measure of the valuable substance of the crop. It would be very incorrect to assume, in all cases, that a given weight of ears at harvest would produce a bushel of dry corn. The moisture and the proportion of cob vary greatly in different varieties. The time of harvest has a marked effect on the amount of water in the crop.

From most of the experiments large samples, representing about an average of the crop, were taken for moisture determinations. Samples of the hard ears (good) and of the soft ears and nubbins (poor) were taken separately. These were partially dried in a warm room, and after the samples had reached about a constant weight, were re-weighed, shelled, and the proportion of corn and cob obtained. Small samples of the grain were then sealed in jars, and taken at once to the laboratory for complete moisture determinations.

With the water-free substance (dry matter) known, the corn could be easily calculated to a uniform water basis. The average amount of water in commercial flint corn is found to be about 11 per cent.* In giving the yields per acre all of the results are reported on this basis.

TABLE 58.

Percentages of Dry Matter of Corn in Ears (Grain and Cob), and the Number of Pounds of Ears Required for a Bushel of Shelled Corn.

NAME AND LOCALITY.	Water-free Corn in Sample (Ears) at Harvest.		Pounds of Ears at harvest to equal 56 lbs. Shelled Corn with 11 % Water.	
	Good.	Poor.	Good.	Poor.
	%	%	Lbs.	Lbs.
R. S. Hinman, Oxford, - - -	66.8	42.1	75	119
K. B. Loomis, South Manchester, -	56.9	43.3	88	115
H. W. Sadd & Son, Wapping, - -	60.3	51.7	83	96
Clifton Peck, Franklin, - - -	56.2	41.5	89	121
J. H. Tucker, Lebanon, - - -	56.1	43.4	89	115
F. L. Ensworth, Canterbury, - -	60.8	59.5	82	84
Jerome Warren, Putnam, - - -	58.6	47.7	86	104

From table 58 it will be seen that the percentages of water-free corn at harvest, on the different fields, vary considerably. These variations are due, in part, to the time of harvest and the weather while the corn is drying in the field, but more largely to differences in varieties. The proportion of cob on Mr. Ensworth's field was small. The variety was an early white flint, and gave very little soft corn, and it will be seen that the number of pounds of ears required for one bushel was lower than for most of the other experiments. The large number of pounds required for a bushel of dry shelled corn in the case of the "poor" corn or nubbins in these experiments, may be explained by the fact that on many fields most of the poor ears were only partially filled out, and hence the proportion of cob was very large. In the case of Mr. Ensworth's experiment, nearly all of the nubbins were hard corn, and, although small, the ears were quite well filled with kernels. Mr. Loomis and Mr. Hinman grew the same variety of corn, yet in the one case there were thirteen pounds more of ears required for a bushel of dry shelled corn (11 per cent. water) than in the other. The results obtained in these two cases help to illustrate the importance of knowing the moisture content in the case of each experiment, rather than assuming a uniform moisture for all.

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*Annual Report of the Connecticut Agricultural Experiment Station, 1888.

SOIL TEST EXPERIMENTS.

The plan of experiments for soil tests consisted in applying on parallel plots of land, fertilizers containing nitrogen, phosphoric acid, and potash, singly, two by two, and all three together. The fertilizing materials were in all cases supplied by the Station, in standard commercial forms, such as nitrate of soda, dissolved bone-black, sulphate of ammonia, dried blood, and muriate of potash. These were mixed under the supervision of the Assistant Agriculturist, a short time before being needed for use. In all of the experiments here described, the cost of the fertilizer is estimated from the retail selling prices of the materials, plus $2.00 per ton for mixing and freights.

Experiments of this class have been carried out at Lime Rock, Oxford, Wapping, Canterbury, Putnam, and at the Station. On the following pages, the comparative yields are shown by means of diagrams. The fertilizers and the weights are given at the left of the diagram. The length of the line represents the comparative yield per acre of shelled corn from the different plots. The figures given in the last column show the number of bushels of shelled corn per acre. At the close of this article will be found a series of tabular statements giving the results in detail. In all cases, the yield of shelled corn per acre is reported on the basis of 11 per cent. water, and the stover on the basis of field weights.

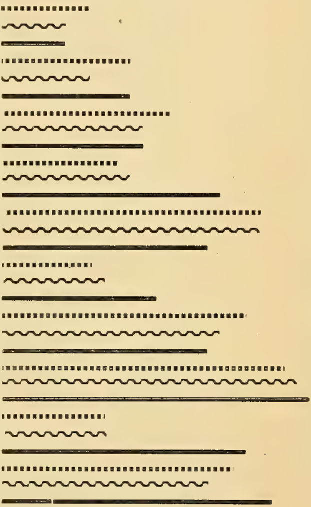
EXPERIMENT BY R. S. HINMAN, OXFORD—P. O. STEVENSON.

Mr. Hinman's field is located near the Housatonic river. The soil is a light loam, with a sandy to gravelly subsoil, and appears to be river terrace formation. The experiment has been continued through four years with the same order of plots and the same kinds and amounts of fertilizers.

Comparative scales, showing the results for the past three years, are published herewith. The first year (1888) is omitted because the results are uncertain, evidently owing to accumulated stores of plant food in the soil. The broken line shows the results for 1889, the wavy line for 1890, and the solid line for 1891. From these it will be seen that the relative yields on the different plots were very similar for 1889 and 1890.

SOIL TEST WITH FERTILIZERS ON CORN.

By R. S. HINMAN, Oxford (P. O., Stevenson).

Plot.	Fertilizers.		Yield Shelled Corn per Acre. (11 % Water.)		
	Kind.	Lbs. per Acre.	Year.	Comparative Scale.	Bu.
A.	Nitrate of Soda,	160	1889		12.2
			1890		8.9
			1891		9.1
B.	Dis. Bone-black,	320	1889		17.4
			1890		12.7
			1891		17.8
C.	Mur. of Potash,	160	1889		22.5
			1890		19.4
			1891		18.8
D.	Nitrate of Soda, Dis. Bone-black,	160 320	1889		15.8
			1890		16.9
			1891		28.9
E.	Nitrate of Soda, Mur. of Potash,	160 160	1889		33.3
			1890		34.5
			1891		27.4
O.	Nothing, - -	—	1889		12.5
			1890		14.4
			1891		19.8
F.	Dis. Bone-black, Mur. of Potash,	320 160	1889		32.0
			1890		28.7
			1891		27.0
G.	Nitrate of Soda, Dis. Bone-black, Mur. of Potash,	160 320 160	1889		37.1
			1890		39.4
			1891		40.3
H	Plaster, - -	400	1889		14.1
			1890		14.4
	Special Mixt.,*	625	1891		32.1
I.	Complete Fertilizer, varied forms, -	600	1889		31.1
			1890		27.2
			1891		35.7

The results for the first two years indicated that potash was lacking in the soil to a greater degree than the other essential ingredients. Wherever potash was omitted the yields were much less than where it was supplied. Compare A, B, and D, with C and E. For both of these years, however, the best results were obtained from the complete mixture (G), but the yields on plot E, without any phosphoric acid, were only 3.8 and 4.9 bushels less than on G.

These facts led to the conclusion in our last report (1890) that potash produced a marked effect on this soil, and that, while phosphoric acid seemed to benefit the crop somewhat, the increase from its use was small. In the experiment for 1891 the relative influence of potash on the total yields is much less than in previous years. The comparatively slight increase from the use of potash this year is probably due to the reduction of the supply of available phosphoric acid in the soil. At present both potash and phosphoric acid appear to be deficient, and need to be supplied in order to produce a fair crop. One lesson that should be drawn from these experiments is that an incomplete fertilizer, like muriate of potash or dissolved bone-black, cannot be applied alone to the best advantage on any soil, for several years in succession. While Mr. Hinman's soil showed large natural stores of phosphoric acid for two or three years, the available supply has gradually become reduced, where none has been added, until this year phosphoric acid seems to be needed nearly as much as potash. In fact, all of the essential ingredients, phosphoric acid, potash, and nitrogen are beneficial, but the proportions of each might be varied so as to meet the deficiencies of the soil. A large amount of potash, with medium quantities of phosphoric acid, would probably give the best results.

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* Nitrate of Soda, 75 lbs.; High-grade Blood, 100 lbs.; Dis. Bone-black, 200 lbs.; Muriate of Potash, 250 lbs.

A mixture was applied on one plot in 1891 with this idea in view. Plot X, during the past season, took the place of plaster (plot H). This plot had the same amount of nitrogen as G (25 lbs.), a large quantity of potash (125 lbs. actual potash), and a small amount of phosphoric acid (32 lbs.). The yield in this case is somewhat less than on plot G, seeming to indicate that a larger proportion of phosphoric acid was needed. The difference may be due, in part, to the accumulation of plant food on G, as more may have been supplied than was taken up by the crop from year to year, while on X the soil has probably been reduced in fertility, as only plaster was applied for three years. A repetition, through one or two years, will be needed to show the best effects of this mixture.

EXPERIMENT BY H. W. SADD & SON.

This experiment has been under the supervision of Mr. R. L. Sadd. The field was part of an old pasture that had not been plowed or fertilized for years. The soil is a light loam, fine in texture, with a porous loam subsoil. There was doubtless considerable plant food supplied the crop from the sod plowed under, and this may account for the rather large yields on the nothing plots.

In this experiment it will be readily seen that potash produced the most marked effect. In all cases where this ingredient was omitted the yields were greatly reduced. Compare B and D with C and E. Nitrate of soda, when used alone, gave no increase over nothing, but when combined with potash (plot E), or in the complete mixture (plot G), it produced a slight increase. A fertilizer containing all of the ingredients, nitrogen, phosphoric acid, and potash, with the potash in quite large proportions, seems to be the best mixture for corn on this soil.

SOIL TEST WITH FERTILIZERS ON CORN.

By H. W. SADD & SON, Wapping.

Plot.	Fertilizers.		Yield Shelled Corn Per Acre. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
O.	Nothing, - -	—		29.1
A.	Nitrate of Soda, -	160		29.6
B.	Dis. Bone-black, -	320		30.0
C.	Muriate of Potash,	160		42.6
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320		37.5
E.	Nitrate of Soda, - Muriate of Potash,	160 160		49.4
F.	Dis. Bone-black, - Muriate of Potash,	320 160		40.5
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash,	160 320 160		49.8
H.	Plaster, - -	400		32.1
OO.	Nothing, - -	—		33.1

EXPERIMENT BY JEROME WARREN.

Mr. Warren's field was part of an old, worn-out meadow, and produced only very light crops of hay for several years previous to 1891. The soil is a clay loam with a compact clay subsoil. In this experiment phosphoric acid produced the most marked effect. Dissolved bone-black gave the best results, whether used alone or in combination with other materials. In all cases where phosphoric acid was omitted the yields were greatly reduced. Potash used alone seemed to produce very little effect, yet when combined with dissolved bone-black (plot

F) the yield was nearly as great as from the complete mixture (plot G). A fertilizer made up mainly of the mineral ingredients, phosphoric acid and potash, with a large proportion of the former, and with small quantities of nitrogen, would doubtless be the most economical on this soil.

SOIL TEST WITH FERTILIZERS ON CORN.

By JEROME WARREN, Putnam.

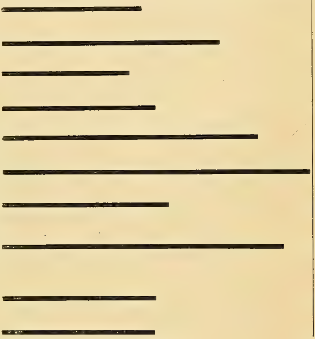
Plot.	Fertilizers.		Yield Shelled Corn Per Acre. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
A.	Nitrate of Soda, -	160		21.3
B.	Dis. Bone-black, -	320		26.9
C.	Muriate of Potash,	160		19.7
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320		31.9
E.	Nitrate of Soda, - Muriate of Potash,	160 160		21.5
F.	Dis. Bone-black, - Muriate of Potash,	320 160		35.7
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash,	160 320 160		36.3
H.	Plaster, - -	400		19.9
00.	Nothing, - -	—		20.7

EXPERIMENT BY F. L. ENSWORTH.

The area used for Mr. Ensworth's experiment was part of a field that had produced a very light crop of oats in 1890. The oats were grown without fertilizer, and were considered too poor to be worth threshing. In 1889 the field had a light application of stable manure, and a light crop of corn was produced. The soil is a sandy loam, with a sandy subsoil. Unlike most of our corn experiments, nitrate of soda produced the most marked effect on this soil, while potash had considerably more effect than phosphoric acid. Compare plots A and C with B. The good effect of nitrogen and potash is also shown on plot E. Plot F, with the mineral fertilizers, but without nitrogen, gave only about half as large a crop as E. The fact that the yield on G, with the complete mixture, is less than that obtained from E, is probably due to differences in the soil. A fertilizer made up largely of nitrogen and potash seems to be the best mixture for corn on this soil.

SOIL TEST WITH FERTILIZERS ON CORN.

By F. L. ENSWORTH, Canterbury.

Plot.	Fertilizers.		Yield Shelled Corn Per Acre. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
o.	Nothing, - -	—		19.7
A.	Nitrate of Soda, -	160		30.3
B.	Dis. Bone-black, -	320		17.8
C.	Muriate of Potash,	160		21.9
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320		36.7
E.	Nitrate of Soda, - Muriate of Potash,	160 160		43.0
F.	Dis. Bone-black, - Muriate of Potash,	320 160		24.2
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash,	160 320 160		40.2
H.	Plaster, - -	400		21.5
oo.	Nothing, - -	—		22.3

EXPERIMENT BY THE STATION.

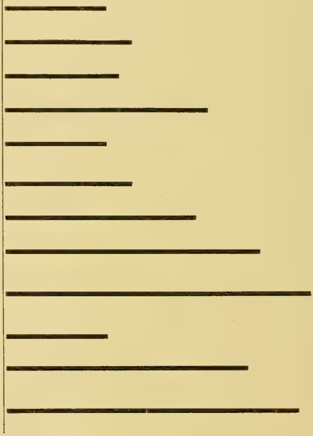
The field upon which this experiment was conducted is the one used for a soil test on corn in 1890, the order of plots and the kinds and amounts of fertilizers remaining the same. A description of the field and the soil will be found on page 69 of the Report of 1890. Owing to irregularities in the soil, the field was laid out as two one-half acre experiments. The entire west side of the field was a poor soil, and hence the order of plots on the two halves was reversed, plots o, A, B, etc., being on the west on one half, and on the east on the other half of the field.

Beside the regular soil test, two other plots were added, one (Y) with a medium amount of stable manure and the other (X) with a smaller quantity of stable manure, but in addition dissolved bone-black at the rate of 160 lbs. per acre. The stable manure was harrowed in just before planting, and the bone-black was applied in the drill.

SOIL TEST WITH FERTILIZERS ON POTATOES.

By THE STATION, Storrs.

Plot.	Fertilizers.		Yield Per Acre.	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
o.	Nothing, - -	—		89
A.	Nitrate of Soda, -	160		105
B.	Dis. Bone-black, -	320		97
C.	Muriate of Potash,	160		171
oo.	Nothing, - -	—		87
D.	Nitrate of Soda, - Dis. Bone-black,-	160 320		110
E.	Nitrate of Soda, - Muriate of Potash,	160 160		160
F.	Dis. Bone-black,- Muriate of Potash,	320 160		214
G.	Nitrate of Soda, - Dis. Bone-black,- Muriate of Potash,	160 320 160		259
ooo	Nothing, - -	—		88
X.	Stable Manure, - Dis. Bone-black, -	10000 160		210
Y.	Stable Manure, -	16000		250



From last year's experiment with corn on this field we give the following:

The growth on the plots having phosphoric acid was heavier and darker colored throughout the season. The results show that phosphoric acid had the most marked effect, nitrogen considerable, while potash gave but little increase over nothing.

The results this year are quite in contrast to those obtained on corn in 1890. In the experiment of 1891 the potatoes responded decidedly to the potash. On all plots where this ingredient was used the vines were heavier throughout the season, remained green longer, and gave much larger yields than plots that received no potash. Phosphoric acid when used alone or in combination with nitrogen brought but little increase over nothing (plots B and D), but when used with potash its beneficial effects were quite marked (plot F). The vines on all of the plots receiving dissolved bone-black, but without potash, were more seriously affected by blight than those on plots having potash. This may account, in part, for the lighter yields on plots B and D. The increased proportion of small potatoes obtained from these plots* would also indicate that the growth of the vines had been prematurely checked. Although potash produced the most marked effect on the yields, phosphoric acid and nitrogen were also needed, as the heaviest yield and the best financial returns were obtained from the complete mixture (plot G).

On plot Y stable manure was used at the rate 8 tons per acre. Assuming the composition to be the same as that of rich stable manure, there were used 80 lbs. of nitrogen, 64 lbs. of potash, and 80 lbs. of phosphoric acid per acre. The value of the manure is ascertained by estimating these ingredients at 15 cents per pound for nitrogen, 6 cents for phosphoric acid, and 4 cents for potash. The yields and the financial returns were less on the manured plots than on the best fertilized plot. Plot X, with 3 tons less of manure than Y, but having, in addition, dissolved bone-black at the rate of 160 pounds per acre, gave a smaller yield than Y with manure alone. Last year (1890) the yields of corn on these plots were nearly the same, while the cost of the mixture on X was about four dollars less than on Y.

OBSERVATIONS ON POTATO BLIGHT.

All of the plots were slightly attacked by blight when nearing maturity, its effects being most noticeable on plots to which dissolved bone-black had been applied. Two applications of Bordeaux mixture with Paris green were applied to the vines, the first, June 26th and 27th, and the second, July 10th and 11th. This appeared to prevent the blight until the potatoes were nearing maturity. During the last week in July, the vines on the plots that had received dissolved bone-black and on the nothing plots, began to show signs of blight. By August 6th the vines on B and D, and on the nothing plots were one-half or more dead, while those on the other plots were slightly affected. The variety of potatoes was an early one, and the crop would probably have matured from August 10th to 20th in a season when no blight occurred.

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* See fuller tabulation on page 194.

SPECIAL NITROGEN EXPERIMENT ON POTATOES.

By MYRON H. DEAN, Falls Village.

Plot.	Fertilizers.		Yield Per Acre.	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
0.	Nothing, - - -	—		88
7.	Mixed Min'ls, as No. 6, Nitrate of Soda, - -	480 160		240
8.	Mixed Min'ls, as No. 6, Nitrate of Soda, - -	480 320		253
9.	Mixed Min'ls, as No. 6, Nitrate of Soda, - -	480 480		242
6*a*.	Dis. Bone-black, Muriate of Potash, *	240 240		171
10.	Mixed Min'ls, as No. 6, Sulp. of Ammonia, -	480 120		197
11.	Mixed Min'ls, as No. 6, Sulp. of Ammonia, -	480 240		217
12.	Mixed Min'ls, as No. 6, Sulp. of Ammonia, -	480 360		198
6*b*.	Mixed Min'ls, as No. 6,	480		144
13.	Mixed Min'ls, as No. 6, Dried Blood, - -	480 200		160
14.	Mixed Min'ls, as No. 6, Dried Blood, - -	480 400		176
15.	Mixed Min'ls, as No. 6, Dried Blood, - -	480 600		195
00.	Nothing, - - -	—		104

* Mixed Minerals, (special).

EXPERIMENT ON POTATOES BY M. H. DEAN.

This experiment was a repetition of the one conducted by Mr. Dean in 1890, with the exception that the proportions of potash and dissolved bone-black in the mixed minerals were changed. In the experiment of 1890 the increase in yield resulting from the use of large quantities of nitrogen was quite small, although a soil test with corn on an adjoining field showed a marked increase in crop from the use of nitrogen. In last year's (1890) experiment, it was thought that the potash might have been applied in too small quantities, and hence the amount was increased in 1891 and the amount of phosphoric acid reduced. This was done on the assumption that if the supply of potash was too small, the crop would fail to utilize the nitrogen, and this appears to have been the case in 1890.

In the experiment for 1891 there was considerable increase in crop where 50 lbs. of nitrogen was used, over that obtained from 25 lbs. Compare plots 8, 11, and 14, with 7, 10, and 13. The best yield was obtained from the use of 320 lbs. of nitrate of soda per acre. The yields where 75 lbs. of nitrogen was applied were less in the case of nitrate of soda and sulphate of ammonia than from 50 lbs., although on the blood plots there was a gradual increase as the amounts of nitrogen increased.

The nitrate of soda mixture gave the largest yields and the best financial returns, while the sulphate of ammonia stood second, and the blood gave the poorest returns. The larger quantities of potash and the smaller amounts of phosphoric acid used in the mixed minerals this year, seemed to meet the deficiencies of the soil better than our regular mixed minerals, such as used last year.

SPECIAL NITROGEN EXPERIMENTS.

The object of this class of experiments is to study the effect of larger and smaller quantities of nitrogen on different crops, while the amount of mineral fertilizers remains constant. There are two prominent points to be considered, the effect of the fertilizer on the yield, and the effect on the composition and feeding value.

Plants differ widely in the readiness with which they respond to applications of nitrogen, and in their peculiar powers of gathering nitrogen from natural sources. Clover, vetches, alfalfa, and other legumes seem to demand but little nitrogen, while grass, oats, and wheat require a great deal, and generally increase in yield with increased applications of this element.

Most of the commercial forms of nitrogen are readily lost to the plant in many soils. The surface soil fails to hold it, especially on light soils with porous subsoils, and on all soils more or less nitrogen escapes in the drainage. Losses of this kind are greatest from quick acting fertilizers, as nitrate of soda and sulphate of ammonia. Nearly all soils retain the mineral constituents quite completely, very little phosphoric acid or potash being found in drainage waters. The question of how to apply nitrogen rationally and economically becomes one of vast importance to the farmer.

Experiments of this kind have been conducted during the past year on grass and potatoes. The experiment on grass will be found on pages 29–40 of this report, and the one on potatoes on page 184.

SPECIAL CORN EXPERIMENTS.

This class of experiments was planned for the purpose of studying the best proportions of phosphoric acid and potash for use in growing corn on soils whose peculiarities had already been studied by means of soil tests. In addition, the profit or loss from the use of the mixtures was considered.

The most profitable mixture for use in growing any particular crop is a difficult matter to ascertain. This depends not only on the adaptability of the fertilizer to the soil and crop, but very largely on the market price of the materials used and on the business tact of the farmer in purchasing. The returns obtained are also dependent upon the season. If drought or an excess of rainfall occurs, the increase, that might otherwise come from the fertilizers, will be greatly lessened. This was well illustrated in the grass experiment, described on pages 29–40. In 1890 nearly all of the mixtures used gave profitable returns, while in 1891, with a much less favorable season for grass, only two of the mixtures were used at a profit.

The object of these experiments was to study the effects of different quantities of the minerals. The nitrogen was kept constant, being supplied in all cases in the form of nitrate of soda, and of dried blood. Previously conducted soil tests showed that the soils where these particular experiments were located were more or less deficient in phosphoric acid, while potash gave but little increase over nothing. For this reason the proportions of these two ingredients were made to vary quite widely. In the first three fertilized plots (A, B, and C,) the nitrogen and potash were kept constant, while the phosphoric acid was used at the rate of 50, 65, and 80 lbs. per acre. In the next three plots (D, E, and F,) the nitrogen and phosphoric acid remained constant, while the potash was used at the rate of 25, 50, and 75 lbs. Of the two remaining fertilized plots, G was supplied with a large amount of potash (100 lbs.) and a small amount of phosphoric acid, (40 lbs.), and H with a large amount of phosphoric acid (80 lbs.) and a small amount of potash (25 lbs.); the cost of the mixtures in the two cases being essentially the same.

EXPERIMENT BY K. B. LOOMIS.

Mr. Loomis' field is a medium compact loam with a reddish clay subsoil. The soil test on this field indicated that phosphoric acid was lacking to quite an extent, while potash was also needed to assure a good crop. From the experiments with special corn mixtures, it appears that both phosphoric acid and potash are lacking. Taking into consideration the results of the past two years, it appears that a mixture containing 25 lbs. of available nitrogen, 300 to 400 lbs. of dissolved bone-black, and 150 to 200 lbs. of muriate of potash, is apt to give a good crop, and at a fair profit.

SPECIAL CORN EXPERIMENT.

By K. B. LOOMIS, South Manchester.

Plot.	Fertilizers.		Yield Shelled Corn per Acre. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
A.	Nitrate of Soda * High Gr. Bl'od * Dis. Bone-black, - Muriate of Potash,	75 100 300 100		37.4
B.	Nit'en mixt. like A, Dis. Bone-black, - Muriate of Potash,	175 400 100		43.0
C.	Nit'en mixt. like A, Dis. Bone-black, - Muriate of Potash,	175 500 100		45.7
D.	Nit'en mixt. like A, Dis. Bone-black, - Muriate of Potash,	175 400 50		44.3
O.	Nothing, - -	—		33.8
E.	Nit'en mixt. like A, Dis. Bone-black, - Muriate of Potash,	175 400 100		50.2
F.	Nit'en mixt. like A, Dis. Bone-black, - Muriate of Potash,	175 400 150		51.6
G.	Nit'en mixt. like A, Dis. Bone-black, - Muriate of Potash,	175 250 200		52.3
H.	Nit'en mixt. like A, Dis. Bone-black, - Muriate of Potash,	175 500 50		50.4
X.	Ashes (home-made)	200		43.0

* Nitrogen Mixture.

EXPERIMENT BY MR. TUCKER.

Mr. Tucker's field adjoins the one used for a soil test in 1889 and for this class of experiments last season, both soils being clay loam with clay subsoils.

In the experiments for 1889 and 1890 the crop responded freely to applications of phosphoric acid, and but very slightly to potash.

In 1891, rather light applications of potash, (100 lbs.), with 400 lbs. of dissolved bone-black, gave the largest yields and the best financial returns. The crop on plot A is not considered in estimating the comparative effects of the fertilizer, as it was influenced by previous manuring.

SPECIAL CORN EXPERIMENT.

By J. H. TUCKER, Lebanon.

Plot.	Fertilizers.		Yield Shelled Corn per Acre. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
O.	Nothing, - - -	—		31.1
A.	Nitrate of Soda }* High Gr. Bl'od Dis. Bone-black, - Muriate of Potash,	75 100 300 100		41.0
B.	Nit'en mixt. like A, Dis. Bone-black, - Muriate of Potash,	175 400 100		39.7
C.	Nit'en mixt. like A, Dis. Bone-black, - Muriate of Potash,	175 500 100		42.2
D.	Nit'en mixt. like A, Dis. Bone-black, - Muriate of Potash,	175 400 50		38.6
E.	Nit'en mixt. like A, Dis. Bone-black, - Muriate of Potash,	175 400 100		43.5
F.	Nit'en mixt. like A, Dis. Bone-black, - Muriate of Potash,	175 400 150		41.0
G.	Nit'en mixt. like A, Dis. Bone-black, - Muriate of Potash,	175 250 200		39.0
H.	Nit'en mixt. like A, Dis. Bone-black, - Muriate of Potash,	175 500 50		36.5
OO.	Nothing, - -	—		24.1

* Nitrogen Mixture.

EXPERIMENT BY MR. PECK.

Mr. Peck's field was on another part of the farm from the one where the soil test was conducted in 1890. The field had been in grass for three years, producing about a ton and a half of hay to the acre. The soil is a clay loam with a clay subsoil.

SPECIAL CORN EXPERIMENT.

By CLIFTON PECK, Franklin (P. O., Lebanon).

Plot.	Fertilizers.		Yield Shelled Corn per Acre. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
O.	Nothing, - -			27.3
A.	Nitrate of Soda * High Gr. Bl'od Dis. Bone-black, - Muriate of Potash,	75 100 300 100		37.0
B.	Nit'en mixt. like A, Dis. Bone-black, - Muriate of Potash,	175 400 100		39.4
C.	Nit'en mixt. like A, Dis. Bone-black, - Muriate of Potash,	175 500 100		46.1
D.	Nit'en mixt. like A, Dis. Bone-black, - Muriate of Potash,	175 400 50		37.1
E.	Nit'en mixt. like A, Dis. Bone-black, - Muriate of Potash,	175 400 100		37.4
F.	Nit'en mixt. like A, Dis. Bone-black, - Muriate of Potash,	175 400 150		37.0
G.	Nitrogen mixt., - Dis. Bone-black, - Muriate of Potash,	175 250 200		35.3
H.	Nitrogen mixt., - Dis. Bone-black, - Muriate of Potash,	175 500 50		35.0
OO.	Nothing, - -	—		28.2
X.	Nitrate of Soda, - Pulv. Bone & Meat, Dis. Bone-black, - Muriate of Potash,	38 338 300 75		42.9

* Nitrogen Mixture.

In the soil test for 1890 phosphoric acid seemed to produce the greatest effect, while potash caused but little increase in crop.

The results this year, although on another field, accord quite closely with those of 1890. The largest yield and the best financial returns were obtained from large quantities of phosphoric acid with rather small quantities of potash. By comparing plots A, B, and C, it will be seen that there was a gradual increase in yield with the increased quantities of dissolved bone-black (phosphoric acid) used.

On plot X was used a special fertilizer prepared by Mr. Peck, the proportions of the materials used in the mixture being based upon the results of the soil test experiment of 1890. The amount of nitrogen was essentially the same as on the other plots, while the phosphoric acid was applied at the rate of about 100 lbs., and the potash 40 lbs. per acre. The cost is based upon the cash cost of the materials per ton in the same way as for the other plots. Mr. Peck, however, purchased at wholesale prices, and the actual cost was less than for the plot giving the largest yield in the Station mixtures. This experiment illustrates the economy of using fertilizers adapted to the soil.

PRACTICAL DEDUCTIONS.*

The results of this year's experiments confirm those of former years, and seem to warrant the following general deductions:

(1.) Soils cannot be cultivated with the greatest profit without a knowledge of their deficiencies in plant food.

(2.) The best practical means of learning the deficiencies of soils, and the most profitable manures for our various farm crops when grown on different soils, seems to be by tests with fertilizers.

(3.) An insight into the subject of the feeding powers of plants is only secondary in importance to a knowledge of the soil. A large number of experiments indicate that the regulating ingredient may vary with different crops on the same soil, a circumstance due, at least in part, to differences in the feeding powers of plants.

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* It is hoped that a Bulletin will soon be issued by the Station, in which the subject of field experiments with fertilizers, covering a period of fourteen years, will be reviewed and summarized. In anticipation of this publication, the practical deductions in this Report are made brief.

(4.) Soils of the same general character usually show the same deficiencies. The experiments of 1891, as well as those of the past three years, indicate that heavy clay soils in Connecticut are generally lacking in phosphoric acid, while light sandy and loamy soils, having porous subsoils, are most apt to be deficient in potash.

(5.) Fertilizers should be so compounded as to meet the deficiencies of the soil, and, at the same time, so as to supply the special needs of the crop. Without a knowledge of the soil, we may be furnishing those ingredients in which the soil abounds, and be withholding just what it lacks. This has been well illustrated in experiments in the Housatonic valley, made during the past three years, where potash is so efficient and phosphates do so little good.

(6.) The relation of plants to the nitrogen supply is one of the most important and difficult problems in the use of fertilizing materials. Experiments made in this State, covering a period of eight years, indicate that soluble nitrogenous fertilizers should be sparingly used, on nearly all soils, for corn; while potatoes, oats, and grass require much larger amounts. On the other hand, the legumes, such as peas, beans, clover, alfalfa, vetches, and lupines are often profitably grown without nitrogen, other than that obtained from the air and that stored in the soil.

(7.) The wide differences found in soils, and in the demands of different crops for plant-food, afford a strong argument in favor of home-mixed fertilizers. Their economy has been well illustrated by farmers in this State. The special needs of different soils cannot be considered by the manufacturer who prepares his goods for general use. The farmer can dispense with the services of middle-men, and prepare such mixtures as will supply the lack found in his soil, and at the same time meet the requirements of particular crops.

TABLE 59.—SOIL TESTS WITH FERTILIZERS ON CORN.

By R. S. HINMAN, Oxford (P. O., Stevenson).

No. of Plot.	Fertilizers Per Acre.			Yield Per Plot. 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % Water.		Stover.	Gain or Loss (-) over Nothing Plots
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
A.	Nitrate of Soda, -	160	3 96	43	41	102	5.7	3.4	1020	-10.7
B.	Dis. Bone-black, -	320	4 40	112	34	133	14.9	2.9	1330	-2.0
C.	Muriate of Potash, -	160	3 48	116	39	124	15.5	3.3	1240	-1.0
D.	Nitrate of Soda, -	160	8 48	194	36	173	25.9	3.0	1730	9.1
	Dis. Bone-black, -	320								
E.	Nitrate of Soda, -	160	7 52	192	22	156	25.6	1.8	1560	7.6
	Muriate of Potash, -	160								
O.	Nothing, - -	—	—	123	41	98	16.4	3.4	980	—
F.	Dis. Bone-black, -	320	8 00	193	16	263	25.7	1.3	2630	7.2
	Muriate of Potash, -	160								
G.	Nitrate of Soda, -	160	12 00	290	19	273	38.7	1.6	2730	20.5
	Dis. Bone-black, -	320								
	Muriate of Potash, -	160								
X.	Special Mixture,* -	625	12 28	221	31	213	29.5	2.6	2130	12.3
I.	Complete Fertilizer Varied forms,	600	12 93	257	17	280	34.3	1.4	2800	15.9

* Nitrate of Soda, 75 lbs.; Blood, 100 lbs.; Muriate of Potash, 250 lbs.; Dis. Bone-bl'k, 200 lbs

TABLE 60.—By H. W. SADD & SON, Wapping.

No. of Plot.	Fertilizers Per Acre.			Yield Per Plot. 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % Water.		Stover.	Gain or Loss (-) over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
O.	Nothing, - -	—	—	221	24	234	26.6	2.5	2340	—
A.	Nitrate of Soda, -	160	3 96	224	25	217	27.0	2.6	2170	-1.5
B.	Dis. Bone-black, -	320	4 40	225	28	213	27.1	2.9	2130	-1.1
C.	Muriate of Potash, -	160	3 48	333	24	290	40.1	2.5	2900	11.5
D.	Nitrate of Soda, -	160	8 48	271	46	268	32.7	4.8	2680	6.4
	Dis. Bone-black, -	320								
E.	Nitrate of Soda, -	160	7 52	384	30	347	46.3	3.1	3470	18.3
	Muriate of Potash, -	160								
F.	Dis. Bone-black, -	320	8 00	314	26	351	37.8	2.7	3510	9.4
	Muriate of Potash, -	160								
G.	Nitrate of Soda, -	160	12 00	400	15	468	48.2	1.6	4680	18.7
	Dis. Bone-black, -	320								
	Muriate of Potash, -	160								
H.	Plaster, - - -	400	1 70	225	48	223	27.1	5.0	2230	1.0
OO.	Nothing, - -	—	—	235	46	227	28.3	4.8	2270	—

SOIL TESTS WITH FERTILIZERS ON CORN.

TABLE 61.—BY JEROME WARREN, PUTNAM.

No. of Plot.	Fertilizers Per Acre.			Yield Per Plot. 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % Water.		Stover.	Gain or Loss (-) over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
A.	Nitrate of Soda, -	160	3 96	145	46	178	16.9	4.4	1780	.6
B.	Dis. Bone-black, -	320	4 40	198	41	176	23.0	3.9	1760	6.2
C.	Muriate of Potash, -	160	3 48	126	52	178	14.7	5.0	1780	-1.0
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320	8 48	248	32	218	28.8	3.1	2180	11.2
E.	Nitrate of Soda, - Muriate of Potash -	160 160	7 52	138	57	205	16.0	5.5	2050	.8
F.	Dis. Bone-black, - Muriate of Potash, -	320 160	8 00	277	36	258	32.2	3.5	2580	15.0
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash -	160 320 160	12 00	281	37	267	32.7	3.6	2670	15.6
H.	Plaster, - - -	400	1 70	124	57	161	14.4	5.5	1610	-.8
OO.	Nothing, - -	—	—	130	58	163	15.1	5.6	1630	—

TABLE 62.—BY F. L. ENSWORTH, CANTERBURY.

No. of Plot.	Fertilizers Per Acre.			Yield Per Plot. 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % Water.		Stover.	Gain or Loss (-) over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
O.	Nothing, - -	—	—	130	33	200	15.8	3.9	2000	—
A.	Nitrate of Soda, -	160	3 96	211	39	226	25.7	4.6	2260	9.3
B.	Dis. Bone-black, -	320	4 40	119	28	200	14.5	3.3	2000	-3.2
C.	Muriate of Potash, -	160	3 48	154	27	240	18.7	3.2	2400	.9
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320	8 48	281	20	255	34.3	2.4	2550	15.7
E.	Nitrate of Soda, - Muriate of Potash, -	160 160	7 52	337	16	316	41.1	1.9	3160	22.0
F.	Dis. Bone-black, - Muriate of Potash, -	320 160	8 00	176	23	285	21.5	2.7	2850	3.2
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash, -	160 320 160	12 00	314	16	334	38.3	1.9	3340	19.2
H.	Plaster, - - -	400	1 70	139	38	213	17.0	4.5	2130	.5
OO.	Nothing, - -	—	—	158	25	224	19.3	3.0	2240	—

EXPERIMENTS ON POTATOES.

TABLE 63—M. H. DEAN, FALLS VILLAGE. TABLE 64—STATION, STORRS.

TABLE 63.—SPECIAL NITROGEN.

Fertilizers Per Acre.				Yield Per Plot. 1-20 Acre.			Yield Per Acre.			
No. of Plot.	Kind.	Weight.	Cost.	Large.	Small.	Total.	Large.	Small.	Total.	Gain over Nothing Plots.
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Bu.	Bu.
0.	Nothing, - -	—	—	179	86	265	59.7	28.7	88.4	—
	Nit. of Soda Group.									
7.	Mix'd Mins., as 6*a*, Nitrate of Soda, -	480 160	12.64	619	101	720	206.3	33.7	240.0	144.0
8.	Mix'd Mins., as 6*a*, Nitrate of Soda, -	480 320	16.54	634	125	759	211.3	41.7	253.0	157.0
9.	Mix'd Mins., as 6*a*, Nitrate of Soda, -	480 480	20.56	613	112	725	204.3	37.3	241.6	145.6
6*a*.	Dis. B-blk., Mxd Mur. Potash, Mns.	240 240	8.64	368	145	513	122.7	48.3	171.0	75.0
	Sul. of Am. Group.									
10.	Mix'd Mins., as 6*a*, Sul. of Ammonia, -	480 120	13.08	514	76	590	171.3	25.3	196.6	100.6
11.	Mix'd Mins., as 6*a*, Sul. of Ammonia, -	480 240	17.52	562	89	651	187.3	29.7	217.0	121.0
12.	Mix'd Mins., as 6*a*, Sul. of Ammonia, -	480 360	21.96	539	56	595	179.7	18.7	198.4	102.4
6*b*.	Mix'd Mins., as 6*a*,	480	8.64	380	51	431	126.7	17.0	143.7	47.7
	Dried Blood Group.									
13.	Mix'd Mins., as 6*a*, Dried Blood, -	480 200	12.59	432	48	480	144.0	16.0	160.0	64.0
14.	Mix'd Mins., as 6*a*, Dried Blood, -	480 400	16.54	454	75	529	151.3	25.0	176.3	80.3
15.	Mix'd Mins., as 6*a*, Dried Blood, -	480 600	20.49	521	64	585	173.7	21.3	195.0	99.0
00.	Nothing, - -	—	—	208	103	311	69.3	34.3	103.6	—

TABLE 64.—SOIL TEST (1-12 ACRE).

0.	Nothing, - -	—	—	266	177	443	53.2	35.4	88.6	—
A.	Nitrate of Soda, -	160	3.96	389	135	524	77.8	27.0	104.8	16.9
B.	Dis. Bone-black,	320	4.40	304	181	485	60.8	36.2	97.0	9.1
C.	Muriate of Potash,	160	3.48	717	136	853	143.4	27.2	170.6	82.7
00.	Nothing, - -	—	—	265	171	436	53.0	34.2	87.2	—
D.	Nitrate of Soda, - Dis. Bone-black,	160 320	8.48	315	236	551	63.0	47.2	110.2	22.3
E.	Nitrate of Soda, - Muriate of Potash,	160 160	7.52	659	142	801	131.8	28.4	160.2	72.3
F.	Dis. Bone-black, Muriate of Potash,	320 160	8.00	880	191	1071	176.0	38.2	214.2	126.3
G.	Nitrate of Soda, - Dis. Bone-black, Muriate of Potash,	160 320 160	12.00	1050	246	1296	210.0	49.2	259.2	171.3
000	Nothing, - -	—	—	256	184	440	51.2	36.8	88.0	—
X.	Stable Manure, - Dis. Bone-black,	10000 160	14.30	876	172	1048	175.2	34.4	209.6	121.7
Y.	Stable Manure, -	16000	19.36	1036	216	1252	207.2	43.2	250.4	162.5

TABLE 65.

SPECIAL CORN EXPERIMENTS.

By K. B. LOOMIS, South Manchester.

No. of Plot.	Fertilizers Per Acre.			Yield Per Plot. 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % Water.		Stover.	Gain over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
A	Nitrate of Soda, High-grade Blood, * Dis. Bone-black, Muriate of Potash,	75 100 300 100	10 38	291	50	457	33.1	4.3	4570	3.6
B	Nitrogen Mixt., like A, Dis. Bone-black, Muriate of Potash,	175 400 100	11 78	339	52	465	38.5	4.5	4650	9.2
C	Nitrogen Mixt., like A, Dis. Bone-black, Muriate of Potash,	175 500 100	13 18	365	48	492	41.5	4.2	4920	11.9
D	Nitrogen Mixt., like A, Dis. Bone-black, Muriate of Potash,	175 400 50	10 68	348	55	460	39.5	4.8	4600	10.5
O	Nothing,	—	—	250	62	352	28.4	5.4	3520	—
E	Nitrogen Mixt., like A, Dis. Bone-black, Muriate of Potash,	175 400 100	11 78	409	42	500	46.5	3.7	5000	16.4
F	Nitrogen Mixt., like A, Dis. Bone-black, Muriate of Potash,	175 400 150	12 88	424	39	553	48.2	3.4	5530	17.8
G	Nitrogen Mixt., like A, Dis. Bone-black, Muriate of Potash,	175 250 200	11 88	430	39	536	48.9	3.4	5360	18.5
H	Nitrogen Mixt., like A, Dis. Bone-black, Muriate of Potash,	175 500 50	12 08	421	30	490	47.8	2.6	4900	16.6
X	Ashes (home made),	200	—	354	32	450	40.2	2.8	4500	9.2

* Nitrogen Mixture.

TABLE 66.

SPECIAL CORN EXPERIMENTS.

By J. H. TUCKER, Lebanon.

No. of Plot.	Fertilizers Per Acre.			Yield Per Plot. 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % Water.		Stover.	Gain over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
o	Nothing,	—	—	230	61	269	25.8	5.3	2690	—
A	Nitrate of Soda, High-grade Blood, * Dis. Bone-black, Muriate of Potash,	75 100 300 100	10 38	336	37	315	37.8	3.2	3150	13.4
B	Nitrogen Mixt., like A, Dis. Bone-black, Muriate of Potash,	175 400 100	11 78	330	30	300	37.1	2.6	3000	12.1
C	Nitrogen Mixt., like A, Dis. Bone-black, Muriate of Potash,	175 500 100	13 18	360	21	326	40.4	1.8	3260	14.6
D	Nitrogen Mixt., like A, Dis. Bone-black, Muriate of Potash,	175 400 50	10 68	317	35	291	35.6	3.0	2910	11.0
E	Nitrogen Mixt., like A, Dis. Bone-black, Muriate of Potash,	175 400 100	11 78	361	33	335	40.6	2.9	3350	15.9
F	Nitrogen Mixt., like A, Dis. Bone-black, Muriate of Potash,	175 400 150	12 88	342	30	318	38.4	2.6	3180	13.4
G	Nitrogen Mixt., like A, Dis. Bone-black, Muriate of Potash,	175 250 200	11 88	316	40	311	35.5	3.5	3110	11.4
H	Nitrogen Mixt., like A, Dis. Bone-black, Muriate of Potash,	175 500 50	12 08	297	36	283	33.4	3.1	2830	8.9
oo	Nothing,	—	—	174	52	207	19.6	4.5	2070	—

* Nitrogen Mixture.

TABLE 67.

SPECIAL CORN EXPERIMENT.

By CLIFTON PECK, FRANKLIN (P. O., LEBANON).

No. of Plot.	Fertilizers Per Acre.			Yield Per Plot. 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % Water.		Stover.	Gain over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
O.	Nothing, - -	—	—	218	34	229	24.5	2.8	2290	—
A.	Nitrate of Soda, * High-grade Blood Dis. Bone-black, - Muriate of Potash, -	75 100 300 100	10.38	306	32	301	34.4	2.6	3010	9.2
B.	Nitrogen Mixt. like A, Dis. Bone-black, - Muriate of Potash, -	175 400 100	11.78	322	39	358	36.2	3.2	3580	11.6
C.	Nitrogen Mixt., like A, Dis. Bone-black, - Muriate of Potash, -	175 500 100	13.18	383	38	407	43.0	3.1	4070	18.3
D.	Nitrogen Mixt., like A, Dis. Bone-black, - Muriate of Potash, -	175 400 50	10.68	306	33	291	34.4	2.7	2910	9.3
E.	Nitrogen Mixt., like A, Dis. Bone-black, - Muriate of Potash, -	175 400 100	11.78	305	38	309	34.3	3.1	3090	9.6
F.	Nitrogen Mixt., like A, Dis. Bone-black, - Muriate of Potash, -	175 400 150	12.88	306	31	286	34.4	2.6	2860	9.2
G.	Nitrogen Mixt., like A, Dis. Bone-black, - Muriate of Potash, -	175 250 200	11.88	289	34	300	32.5	2.8	3000	7.5
H.	Nitrogen Mixt., like A, Dis. Bone-black, - Muriate of Potash, -	175 500 50	12.08	287	34	295	32.2	2.8	2950	7.2
OO.	Nothing, - -	—	—	225	35	250	25.3	2.9	2500	—
X.	Nitrate of Soda, - Pulv. Bone and Meat, Dis. Bone-black, - Muriate of Potash, -	37.5 337.5 300.0 75.0	13.54	353	39	351	39.7	3.2	3510	15.1

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* Nitrogen Mixture.

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Publications of the Station.

The publications of the Station will be mailed to all citizens of Connecticut, and to Granges, Farmers' Clubs and other agricultural organizations who ask for them, and so far as circumstances permit, to those who apply from other States. Requests for publications and business communications should be addressed to

STORRS SCHOOL AGRICULTURAL
EXPERIMENT STATION,
TOLLAND COUNTY. STORRS, CONN.

STATE OF CONNECTICUT.

FIFTH ANNUAL REPORT

—OF THE—

STORRS SCHOOL

AGRICULTURAL EXPERIMENT STATION,

STORRS, CONN.

1892.

Printed by order of the General Assembly.

MIDDLETOWN, CONN.:
PELTON & KING, PRINTERS AND BOOKBINDERS.
1893.

PUBLICATIONS OF THE STATION.

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STORRS SCHOOL AGRICULTURAL
EXPERIMENT STATION,
STORRS, CONN.

Tolland County.

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BOARD OF TRUSTEES

—OF THE—

STORRS AGRICULTURAL SCHOOL.

His Excellency Luzon B. Morris.

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J. H. Hale,
T. S. Gold,
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The Station is located at Mansfield (P. O. Storrs), as a department of the Storrs Agricultural School. The chemical and other more abstract work is carried out at Wesleyan University, Middletown.

OFFICERS OF THE STATION.

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C. D. Woods, Middletown,	*Vice-Director and Chemist.*
C. S. Phelps, Storrs,	*Agriculturist.*
S. H. Buell, Storrs,	*Assistant in Farm Experiments.*

Report of the Executive Committee.

To His Excellency Luzon B. Morris,
Governor of Connecticut:

In accordance with the resolution of the General Assembly concerning the congressional appropriations to Agricultural Experiment Stations, and an Act of the General Assembly, approved March 6th, 1889, relating to the publication of Reports of the Storrs School Agricultural Experiment Station, we have the honor to present herewith the Fifth Annual Report of that Station, namely, that for the year 1892.

The Director, Prof. W. O. Atwater, has been in Europe a part of the year. In his absence the Vice-Director, Charles D. Woods, has had the charge of the work of the Station, and has been responsible for the details of its operations.

The following changes in the Station staff have been made during the year: Mr. E. A. Bailey, Assistant Agriculturist, and Mr. H. M. Smith resigned their positions July 1st, and at the same time Mr. S. H. Buell was appointed Assistant in Farm Experiments.

The Committee refer to the accompanying report of the Treasurer for details of expenditure, and to that of the Director and his associates for the history of the work accomplished, and express their confident belief that the funds have been wisely expended and the work such as will result in great benefit to our agricultural interests.

Respectfully submitted,

T. S. GOLD,
J. M. HUBBARD,
B. F. KOONS,
Executive Committee.

Report of the Treasurer

FOR THE FISCAL YEAR ENDING JUNE 30, 1892.

The following summary of receipts and expenditures is made out in accordance with the form recommended by the Association of American Agricultural Colleges and Experiment Stations, and approved by the United States Treasury Department:

TABULAR STATEMENT OF RECEIPTS AND EXPENDITURES.

RECEIPTS.	
U. S. Treasury,	$7,500 00
Hon. J. W. Alsop, through Wesleyan University,	125 00
Sale of produce and dairy products,	227 79
Balance from 1890–91,	4 55
	$7,857 34

EXPENDITURES.	
Salaries,	$4,257 03
Building,	371 41
Traveling expenses,	141 15
Executive Committee,	93 69
Stationery,	46 06
Postage, telegraph and telephone,	79 04
Treasurer,	52 20
Fixtures, permanent,	23 17
Fixtures, not permanent,	37 96
Bulletins and reports,	189 00
Library,	4 95
Field experiments, labor,	100 39
Field experiments, other than labor,	280 54
Team,	126 78
Feeding experiments,	385 17
Student and other labor,	440 05
Apparatus, immediate,	173 91

Apparatus, permanent,	$335 74
Chemicals,	120 67
Coal, gas and oil,	217 97
Hardware and lumber,	39 51
Freight, cartage and express,	46 98
Bacteriological investigations,	112 08
Office furniture,	12 50
Incidentals,	38 84
Balance in treasury,	130 55
	$7,857 34

HENRY C. MILES,
Treasurer.

This will certify that we have examined the accounts of Henry C. Miles, Treasurer of the Storrs School Agricultural Experiment Station, for the fiscal year ending June 30, 1892, compared the vouchers therewith and find the same correct, showing a balance in said Treasurer's hands at the close of said fiscal year amounting to $130.55.

D. WARD NORTHROP, } *Auditors of*
BENJAMIN P. MEAD, } *Public Accounts.*

MILFORD, CONN., December 24, 1892.

Report of the Director.

The lines of experimental work in which this Station has been engaged during the past year are, for the most part, in continuation of those previously begun. They have been as follows:

1. Co-operative field experiments with fertilizers by the Station and by farmers on their own farms in different parts of the State. These experiments are the same in character and scope as those of previous years.

2. Observations on the growth of grass and forage plants at the Station and elsewhere, with especial reference to the cultivation of legumes.

3. Experiments upon the acquisition of atmospheric nitrogen by growing plants.

4. Meteorological observations at the Station throughout the year, and observations of the rainfall in connection with the field experiments in different parts of the State during the growing season.

5. Experimental studies of the bacteria of milk and their action.

6. Feeding experiments with milch cows.

7. Investigations of dietaries and studies of the chemical composition of the food of man. The studies of dietaries have been made in connection with the U. S. Department of Labor.

8. Investigations with the calorimeter upon the heats of combustion of materials used as food for domestic animals and man.

9. Preliminary experiments in the elaborating of a calorimetric respiration apparatus.

My duties in connection with the Office of Experiment Stations of the Department of Agriculture at Washington and in Europe, have been such that for a considerable part of the past year I have been able to exercise only a general supervision of the work of the Station. It would be wrong to omit an expression of appreciation of the efficient manner in which the Vice-Director, Mr. Charles D. Woods, has, during my absence, performed the duties of Acting Director. I desire also to bear witness to the ability and faithfulness with which all of the gentlemen associated with me have executed the work intrusted to them.

SUMMARY OF THE PRESENT REPORT.

THE ASSIMILATION OF THE FREE NITROGEN OF THE AIR BY PLANTS. PAGES 17–22.

In accounts of investigations reported by the writer in 1881–5, in which peas were shown to acquire large quantities of nitrogen from the air, it was urged that the fixation of free nitrogen, though not absolutely proven, was extremely probable. Later researches by Hellriegel, Lawes and Gilbert, and others in Europe, and by this Station, have confirmed the assimilation of free nitrogen. A series of experiments was devised for the purpose of inquiring into the ways by which the plants acquire the nitrogen, but circumstances have thus far prevented their being carried out, and only the preliminary trials have been made. In these trials pea plants were grown without access to combined nitrogen either in the air or the soil (sand) or the fertilizing materials or otherwise, except the very minute quantity in the soil infusions with which the roots were inoculated and of course, that in the seed. The plants when mature showed a considerable gain of nitrogen, which must have come from the free nitrogen of the air.

ANALYSES OF FODDERS AND FEEDING STUFFS.—PAGES 23–35.

Analyses of about 150 specimens of miscellaneous feeding stuffs, mostly grasses and other forage plants, field-cured grains and some milling products, have been made during the year by the Station chemists, in connection with feeding experiments or experiments upon the growth of plants. In no case were the analyses undertaken merely to increase the number of data of this class, though they are of course valuable for that purpose.

SPECIAL NITROGEN EXPERIMENT ON GRASS.—PAGES 36–46.

The object of this experiment is to study the effect of nitrogenous fertilizers upon grass, as shown by the yield per acre, the chemical composition of the hay, and the financial results. The plan consists in applying different fertilizers to parallel plots of land, and weighing and analyzing the produce. The experiment has been continued through several successive years, with the same fertilizers on the same plots. The plots contained one-eighth acre each, and were separated from each other by unfertilized strips. Mineral fertilizers, supplying phosphoric acid and potash, were applied to all the plots except one, which was left unmanured, and, with one exception, nitrogen was applied to the manured plots at the rate of 25, 50, and 75 pounds per acre. The results are summarized by Messrs. Woods and Phelps as follows:

The addition of mineral fertilizers increased the yield of clover, but did not seem to increase very materially the yield of grasses. In general the yield of hay increased with the quantity of nitrogen supplied. The mineral fertilizers when used alone were applied at a financial loss. The application of 160 pounds of nitrate of soda per acre (25 lbs. of nitrogen), in addition to the mixed minerals, gave an average profit during the three years of $1.40 per acre; 320 pounds of nitrate of soda (50 lbs. of nitrogen) gave an average profit of $5.24 per acre, and 480 pounds of nitrate of soda (75 lbs. of nitrogen) an average profit of $2.45 per acre. The returns from 320 pounds were very uniform, the profit being $5.10, $5.12 and $5.49 respectively for the three years. The application of nitrogenous fertilizers increased the percentages of protein in the crop and somewhat in proportion to the amount of nitrogen supplied. The increase in the amount of nitrogen in the crop did not equal the increased amount of nitrogen supplied in the fertilizers, thus implying that the plants were not able to utilize all the nitrogen supplied.

EFFECTS OF DIFFERENT FERTILIZERS UPON THE COMPOSITION OF OATS AND STRAW.—PAGES 47–56.

This work, which is in continuance of an investigation described in the Annual Report of the Station for 1890, was undertaken with the hope of getting more light upon the effects of different fertilizers upon the percentage composition, and upon the total yield of nutritive ingredients of the grain and straw of the oat plant, with special reference to the effect of nitrogenous fertilizers upon the amounts of protein. The plan is similar to that of the experiments on grass just referred to. The results are stated by Mr. Woods as follows:

The crops from two special nitrogen experiments with oats and one soil test experiment with oats have been analyzed. The percentage of protein increased in both oats and straw with the application of nitrogen in the form of nitrate of soda or sulphate of ammonia, and this increase was somewhat in proportion to the amounts applied. In the experiment of 1890 the use of different amounts of dried blood in the fertilizer did not materially affect the percentages of protein in either the oats or the straw. In 1892 there was an increase in the protein from the use of the largest amount (75 pounds nitrogen per acre) of dried blood. There was an increase in pounds of protein per acre in the plots supplied with nitrogenous fertilizers, somewhat in proportion to the amounts applied. This increase was greatest in the plots on which nitrate of soda was used. These results are in accord with observations made by the Station upon the relation of the protein in corn, and in grass, to the nitrogen applied in the fertilizers.

EFFECT OF NITROGENOUS FERTILIZERS UPON THE PERCENTAGES OF PROTEIN IN GRASSES AND GRAINS.—PAGES 60–66.

The outcome of 73 field experiments, during several years past, upon the effect of nitrogenous fertilizers upon the protein of the crop, are concisely summed up by Mr. Woods, as follows:—

Results of Analyses showing Relation between Nitrogen applied in Fertilizers and Protein found in Resulting Crops.

Kind of Crop.	No. of Experiments.	Phosphoric Acid and Potash (Mixed Minerals).	Mixed Minerals and 25 lbs. Nitrogen per acre.	Mixed Minerals and 50 lbs. Nitrogen per acre.	Mixed Minerals and 75 lbs. Nitrogen per acre.
		%	%	%	%
Corn (grain),	22	10.9	11.3	11.4	12.1
Oats (grain),	5	15.1	15.4	15.7	16.3
Corn stover,	22	6.2	6.6	6.6	7.6
Oat straw,	5	5.3	4.7	5.2	6.0
Mixed grasses,	5	7.6	7.6	8.8	9.8
Orchard grass,	2	8.9	10.2	—	12.6
Timothy,	2	7.7	8.1	—	10.6
Red-top,	3	—	8.3	—	11.7
Seven other pure grasses,	7	—	10.2	—	12.1

The results as shown in the table need no explanation, as the figures tell the story so plainly. In general, the percentages of protein increased with the amount of nitrogen applied, though, in most cases, the application of the largest amount of nitrogen seemed to have the most marked effect upon the protein of the crop.

PRACTICAL CONCLUSIONS REGARDING NITROGENOUS FERTILIZERS AND FEEDING STUFFS.

The Station has for years been urging upon the attention of farmers the value of nitrogenous feeding stuffs. The progress of exact experiment is bringing out the desirability of such materials more and more clearly. Thus the experiments on the effects of fodder upon the production of milk and meat lately made in Experiment Stations in the United States and in Europe, emphasize most forcibly the need of rations much richer in protein than most of our farmers feed.

Our crops contain a large excess of the materials which serve as fuel, while the protein compounds, which make muscle, bone, and milk, are relatively wanting. The farmer is primarily responsible for this state of affairs, and must be the one to take the first steps to amend it. The protein needed for the use of the stock kept on the farm may be obtained in one of three ways: It may be purchased in the form of concentrated feeds, such as wheat bran, oil meals, etc.; it may be obtained by growing the legumes which are able to obtain nitrogen directly from the air and convert it into protein; or it may be obtained by breeding and importing varieties of grains and grasses richer in nitrogen than those now cultivated. While it is probable that the feeder must, for the present, continue to buy some of the protein which his animals need, still by care in selection of crops, and by growing plants richer in nitrogen, much more protein may be produced on the farm itself. This protein is needed for fodder in order to make leaner meat, and more of it, and more milk at less cost. The nitrogen not transformed into meat or milk makes rich manure for grasses, grains, and other crops, and the rich manure helps to bring larger crops, and crops richer in protein.

RESULTS OF EXPERIMENTS WITH FERTILIZERS ON DIFFERENT CLASSES OF SOILS.—PAGES 67–84.

The reports of about 90 soil test experiments with fertilizers, conducted in this and other New England States during the past 15 years, on plans suggested by the writer, have been studied by Prof. Phelps with reference to the classes of soils, for the purpose of ascertaining the relations, if any, between the kinds of soils and their deficiencies. The results have been summarized in two groups: (1) soils ranging from sandy to loam, and (2) soils ranging from heavy loam to heavy clay. The teachings of the experiments thus far made in Connecticut imply that for soils in this state generally, though of course there may be exceptions:

Nitrogen.—This is more apt to be beneficial on the light than on heavy soils. Soluble fertilizers, as nitrate of soda and sulphate of ammonia, can generally be used with profit on light loam soils, but do not prove of much value for corn on heavy soils. For heavy soils nitrogen should be supplied in some organic form, as stable manure, dried blood, etc.

Phosphoric Acid and Potash.—Heavy, clayey soils need to be supplied with large amounts of phosphoric acid in the fertilizers used, while light, sandy to loam soils are more generally, though not uniformly, helped by potash fertilizers.

The wide differences found in soils afford a strong argument in favor of home mixed fertilizers. The special needs of different soils cannot be considered by the manufacturer who prepares his fertilizers for general use. The farmer may, however, prepare such mixtures as will meet both the deficiencies of his soil and the requirements of his crops.

CO-OPERATIVE FIELD EXPERIMENTS WITH FERTILIZERS.—PAGES 85–105.

The Station has continued its coöperative field experiments through a fifth year, the plan being similar to that of former years. Seven "soil test" experiments upon corn and one "soil test" and one "special nitrogen" experiment with oats have been made by farmers in different parts of the State during the past year, and are reported upon by Prof. Phelps.

BACTERIA IN THE DAIRY.—PAGES 106–126.

Prof. Conn has continued his investigations, in connection with the Station, upon bacteria in the dairy and in the present Report gives a paper upon *The Isolation of Rennet from Bacteria Cultures.* He describes in detail the experiments and the species of bacteria studied. His conclusions are as follows:

Many species of bacteria that have the power of liquefying gelatine, produce, as a result of their growth in milk, a certain quantity of an enzyme which, so far as can be at present determined, has all of the essential characteristics of rennet. This rennet can be isolated from bacteria cultures by filtering the cultures through a porcelain cylinder and then treating the filtrate with alcohol. A better method, which gives the rennet in a purer condition, though by no means pure, is to precipitate it from its solution by an excess of salt instead of alcohol. It has been found possible to isolate this rennet from milk in the case of all species of bacteria thus far studied which curdle the milk without rendering it acid. Different species of bacteria differ very much in the amount of rennet which they produce and the rapidity with which they produce it. Several species of bacteria have been found to produce rennet in considerable quantity, even where they are not capable of curdling the milk. The explanation of the fact is that the production of a tryptic ferment obscures the production of the rennet ferment in these cases, and the casein becomes peptonized before it can be precipitated by the more slowly forming rennet. The organisms experimented upon seemed in every case to produce a larger amount of rennet when growing at a moderately low temperature than when growing at a temperature of 35° C. The rennet isolated in this way has all of the general reactions of dairy rennet, and is subject to destruction by high temperatures in a similar manner.

A STUDY OF ACTUAL DIETARIES.—PAGES 135–162.

During the year the Station has studied the dietaries of families of a jeweler, a blacksmith, a machinist, a mason, and two carpenters. The results are given in detail and a summary of the results of these and the two other dietaries previously examined is appended in the account of the work by Mr. Woods.

ECONOMY OF FOOD.—PAGES 163–190.

The cost of food is the principal item of the living expenses of the majority of the people—of all, indeed, but the especially well-to-do. Wage-workers and people of moderate incomes generally in Connecticut and the Eastern States spend and must spend over half their earnings for food. Although the cost of food is so great, and although the health and strength of all are so dependent upon their diet, yet even the most intelligent people know very little about the actual uses and values of their food for fulfilling its purposes. The result is great waste in the purchase and use of food, loss of money, and injury to health.

The last Annual Report of this Station gave accounts of chemical analyses of a considerable number of our common food materials; results of studies of the kinds, amounts and composition of the food actually eaten in families and boarding houses in New England; and some comparisons between these dietaries and those of people in corresponding circumstances in Europe. The present report describes further studies and discusses the chemical composition, digestibility, and nutritive values and pecuniary economy of foods.

Examinations of Dietaries.—An important part of the inquiry is the examination of the food purchased and used by people, mostly wage-workers, which has been undertaken in connection with the United States Department of Labor. The method consists simply in making arrangements with families and boarding houses, by which not only all food purchased but the unconsumed portions also, the kitchen and table wastes, are weighed and specimens taken for analysis. At the same time account is kept of the number of persons at the table and the number of meals eaten by each. In this way it is possible to learn exactly the kinds and proportions of actual nutrients eaten and compare them with those required by physiological standards. The same investigations show, of course, just how the nutritive material consumed compares with the cost, and in how far the food is economically or wastefully used.

Home Studies of Dietaries.—Efforts are being made to aid intelligent private families to make studies themselves of their food consumption. The results thus far are decidedly encouraging.

Mistakes in our Food Economy.—The studies thus far made point to four errors in our food economy: We buy needlessly expensive kinds of food; many of us use more than we need; that which we consume is very apt not to contain the different nutritive ingredients in the proportions best adapted to our needs for nourishment, we use an excess of meats and sweetmeats; and, finally, we throw away a great deal of food that ought to be utilized.

Cheap vs. Dear Food.—The cheapest food is that which supplies the most nutriment for the least money. The most economical food is that which is the cheapest and at the same time best adapted to the wants of the user. The maxim that "the best is the cheapest" does not apply to food. The best food in the sense of that which is the finest in appearance and flavor and which is sold at the highest price, is not generally the cheapest, nor is it always the most healthful or economical.

A quarter of a dollar invested in the sirloin of beef at 22 cents per pound pays for one and one-seventh pounds of the meat with three-eighths of a pound of actually nutritive material. This would contain one-sixth of a pound of protein to make blood and muscle, and one-fifth of a pound of fat, and supply 1,120 Calories of energy, *i. e.*, heat to keep the body warm and muscular power for work. The same amount of money paid for oysters, at the rate of 50 cents per quart, brings two ounces of actual nutrients, an ounce of protein, and 230 Calories of energy. But in buying wheat flour at seven dollars a barrel, the 25 cents pay for six and a quarter pounds of nutrients, with eight-tenths of a pound of protein and 11,755 Calories of energy.

Waste of Food.—We waste food in two ways. We eat more than we need, and a great deal is simply thrown away. That which is rejected in kitchen and table refuse does no harm, but that which we consume in excess of our needs is worse than wasted, because of the injury it does to health. In some of the dietaries examined from one-ninth to one-twelfth of the nutritive material was simply thrown away, and, what made the matter still worse from the pecuniary standpoint, the portions thus rejected were mostly from the meats, in which the nutritive ingredients are the most costly.

Food of the Poor.—The saddest part of the whole story is that it is the poor man's money that is the most uneconomically spent in the market, and the poor man's food that is worst cooked and served at home. Indeed it is as surprising as it is pathetic to see how much people of limited incomes lose in this way. Here it is true that "To him that hath shall be given, and from him that hath not shall be taken away even that which he hath."

What Needs to be Done?—The first step toward dietary reform is the getting of a better understanding of the facts; the next, the diffusing of these among the people. What has been reported by the Station is of course only a beginning and a very small one in this direction, but it is hoped that it may not be without usefulness.

W. O. ATWATER,
Director.

THE FIXATION OF FREE NITROGEN BY PLANTS.

BY W. O. ATWATER AND CHAS. D. WOODS.

In the Annual Report of this Station for 1890* reference was made to plans then in contemplation for experiments upon the fixation of nitrogen by plants. In accounts of investigations reported by one of us (W. O. A.) in 1881–85, in which peas were shown to acquire large quantities of nitrogen from the air, it was urged that the acquisition of free nitrogen, though not absolutely proven, was extremely probable. Researches since then by Hellriegel and Wilfarth, Wolff, Breal, Lawes and Gilbert, Frank, Schloessing and Laurent, Petermann, and others, including the writers, have placed the fixation of free nitrogen of the air by plants beyond doubt, and have shown that micro-organisms are in some way connected with the process.† The especial purpose of the experiments here contemplated was the study of the ways by which the nitrogen is obtained through either the roots or the foliage or both. Circumstances have thus far prevented the carrying out of the inquiry with the details proposed, and only a series of preliminary trials on the growth of plants in an atmosphere freed from compounds of nitrogen has been completed. While the results prove nothing essentially new, they are worth reporting in brief as confirmatory evidence of the fixation of the uncombined nitrogen of the air.

PLAN OF EXPERIMENTS.

It was desired to grow the plants under conditions as nearly normal as possible, but with entire exclusion of nitrogen compounds from both the air and the medium containing the roots. For this purpose a glass case was so constructed as to insure air-tight closure and yet afford convenient access to the plants from time to time. It was, indeed, in principle and in appearance a large Wardian case, and was located in a greenhouse. A stream of air carefully washed by water, alkali, and acid, was caused to flow through the case. Carbon dioxide was added each day in quantities judged to be sufficient for the needs of the plants. The whole apparatus was inside of a greenhouse whose temperature could be fairly well regulated. Pea plants were used for the experiment, as we had better success with them than with other legumes in our previous experience. They were grown in purified sea sand, supplied with nutritive solutions, inoculated with soil extract, and, with the exception of the watering as stated beyond, were treated as were those of the experiments previously described.* Considerable difficulty was found in maintaining the temperature of the case at low enough point for the healthy development of pea plants. A series of experiments undertaken in the spring months gave rather poor growth, presumably from the high temperature in the sunshine. To obviate this, another series, which is here reported upon, was undertaken late enough in the fall, so that by thoroughly ventilating the greenhouse, the temperature inside the case could be kept within reasonable limits.

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* Page 12.

† See *Am. Chem. Journal* VI., sec. 68; VIII., 368; Annual Reports of this Station for 1889, p. 11; 1890, p. 12, and 1891, p. 17, and review of history of the subject with especial references to the relations of root tubercles to the acquisition of nitrogen in Experiment Station Record, III., p. 56.

DETAILS OF EXPERIMENTS.

The case was constructed of wood and glass; it was 6 feet in length, 4½ feet in width, and 4 feet in height. The joints were carefully made, and the glass was bedded and laid with white lead putty. It had no bottom. The platform on which it rested and by which it was closed was covered with sheet lead. The four sides of the case had on the lowest edge a square tongue, one inch thick and one inch deep, which projected into a corresponding groove or channel in the platform, so that when the channel was filled with an appropriate liquid as water or mercury or glycerine—the last was actually used—connection between the atmosphere within and without the case was efficiently cut off. Ropes and a pulley above made it easy to raise and lower the case as occasion demanded.

Circulation of Air.—A current of purified air was forced through the case with the aid of a pump such as is used in the manufacture of gasoline gas. The air passed through a meter by which the volume was measured and the rate of flow was regulated accordingly. The quantity passed through per day was about equal to the volume contained in the case, *i. e.*, not far from 100 cubic feet.

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* Reports of this Station, 1889, pp. 11–51; 1890, pp. 12–14; 1891, pp. 17–28.

Purification of Air.—Between the pump and the case the air was passed through a solution of sodium of carbonate to absorb the nitric and nitrous acids, and then through a solution of sulphuric acid to free it from ammonia. The washing solutions were in carboys of about 18 liters capacity, so that the air was in contact with them for a much longer time than while merely bubbling through the solutions. The pump itself was so constructed that all of the air introduced had to pass through water. This insured the washing out of atmospheric dust and of a large part of the ammoniacal salts, nitrites, and nitrates. In cases in which the test was made, it was not until 75 or 100 cubic feet of air had passed through the pump that it began to give a perceptible color in passing through a solution containing Nessler's reagent. Only a part of the nitrogen compounds had to be removed by the alkaline and acid solutions in the carboys. The gases thus washed were tested from time to time by passing through a solution containing Nessler's reagent. In no instance was ammonia detected, although the periods of flow of the air through the solution were of considerable length.

The presence or absence of ammonia was further tested by keeping sulphuric acid in an open vessel within the case throughout the whole period of the experiment. At the beginning 15 cc. of strong sulphuric acid were placed in a flat bottomed porcelain dish having a diameter of about 11 cm. At the end of the experiment the acid solution had increased in volume by absorption of water to about 250 cc. This was rendered alkaline by the addition of sodium hydroxide, which was free from ammonia, and was then tested with Nessler's reagent. There was the faintest possible coloration, but the amount of ammonia was too slight for estimation. The same amount, 15 cc., of fresh strong sulphuric acid was diluted to like volume with ammonia-free water and then neutralized as above. This gave as much color with Nessler's reagent as did that which had been in the case for 85 days. It thus seems reasonable to conclude that there was at no time any considerable amount of ammonia in the atmosphere within the case.

It was assumed that washing the air in both water and alkali solution freed it completely from nitric and nitrous acids.

Supply of Carbon Dioxide.—By a convenient arrangement carbon dioxide was introduced into the case each day in such quantity as was deemed desirable for the proper growth of the plants. In general the atmosphere within the case contained from three to six times as much carbon dioxide as ordinary air.

Pots. Sand.—The plants were grown in glass jars, placed in boxes, similar to those described in earlier reports. They contained sea sand, which had been carefully washed and ignited so as to reveal no trace of nitrogen compounds when tested by either the soda lime or the Kjeldahl method.

Nutritive solutions. Planting. Inoculation—The nutritive solutions were all made with specially prepared, "nitrogen-free" water, *i. e.*, water which had been distilled with alkali, and potassium permanganate, and gave no appreciable reaction for ammonia with Nessler's reagent. They supplied the plants with the needed mineral constituents, but included no compounds of nitrogen. The seeds were planted before germination. At time of planting the nutritive solutions were applied and "nitrogen-free" water was added in sufficient amount to moisten all of the sand in the jar. In order to insure inoculation with the organisms which produce root tubercles, 25 cc. of infusion prepared from soil in which pea plants developing large numbers of root tubercles had been grown, were added at two periods, once at the time of planting the seeds and again when the plants were in the third leaf.

Watering.—The atmosphere of the case was saturated with moisture to such an extent that although the experiment continued for nearly three months, the soil in which the plants grew never became sufficiently dry to seem to need additional supplies of water. Accordingly, the water added at the beginning of the experiment was all that was supplied the plants. The pots, sand, "nitrogen-free" water, soil infusion, and the methods of their preparation and use are described in the account of previous experiments.*

RESULTS OF EXPERIMENTS.

Under such circumstances as these in which the plants were placed, their development was as nearly normal as could be expected. The height was generally as great as is usual with dwarf peas, but the yield of seed was small.

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*Report of this Station, 1889, pp. 16-20.

The table (1) herewith gives the principal statistics of the experiments.

TABLE I.

Pea Plants Grown in Sand in Glass Jars—No Compounds of Nitrogen in Air, Soil, or Nutritive Solutions.

Reference Numbers.	Height.	No. of Peas.		Root Development.	Tubercle Development.	Weight of Mature Plants (air dry).			Nitrogen Statistics.		
		Mature.	Immature.			Tops.	Roots.	Total.	Nitrogen in Seed.	Nitrogen in Plant at end of exp't.	Gain of Nitrogen.
	in.					Mg.	Mg.	Mg.	Mg.	Mg.	Mg
566,	27	1	2	Poor.	Fair.	500	290	790	10	16	6
567,	43		3	Fair.	Good.	760	470	1230	10	30	20
568,	32	2	1	Good.	Fair.	560	480	1040	10	18	8
569,	30	3		Good.	Fair.	770	640	1410	10	25	15
571,	21	1	1	Poor.	Good.	400	230	630	10	11	1
572,	37	2		Good.	Few.	570	370	940	10	15	5
573,	30	1	2	Poor.	Few.	500	270	770	10	16	6
574,	34	3		Fair.	Fair.	820	420	1240	10	22	12
575,	24	1		Fair.	Very few.	490	290	780	10	14	4
576,	27	2	1	Fair.	Fair.	600	260	860	10	20	10
577,	29			Good.	Very few.	420	530	950	10	12	2
578,	23	2		Good.	Few.	470	400	870	10	16	6
579,	34	1	1	Fair.	Very few.	590	720	1310	10	16	6
580,	29	2		Good.	Good.	700	260	960	10	22	12
581,	31	2		Good.	Good.	710	450	1160	10	20	10
582,	32	2	1	Fair.	Fair.	960	590	1550	10	29	19
583,	29	2		Fair.	Good.	630	130	760	10	19	9
584,	27	1	1	Good.	Few.	440	200	640	10	12	2
585,	29	2		Fair.	Good.	670	240	910	10	20	10
586,	31	2	1	Good.	Good.	660	450	1110	10	21	11
587,	25	2		Good.	Fair.	470	140	610	10	13	3
588,	28	2	2	Good.	Good.	720	150	870	10	23	13
589,	33	2	1	Good.	Good.	850	100	950	10	27	17
590,	30	3	2	Good.	Fair.	950	570	1520	10	25	15
591,	26	2		Poor.	Fair.	520	200	720	10	16	6
592,	28	2		Good.	Good.	630	240	870	10	18	8
593,	30	2		Fair.	Fair.	530	260	790	10	16	6

The root development was designated "poor," "fair," or "good," according to the amount of roots found at the end of the experiment. The number of root tubercles is spoken of as "very few," "few," "fair," or "good," in accordance with their abundance as compared with the amount of roots. What would be a "fair" or even a "good" development of root tubercles with "poor" roots might be classified as "few" with "good" roots. Hence, in judging of the tubercle development as indicated in the table, it is necessary to consider the root development as well as that of the tubercles themselves. Of course, such a classification is indefinite and entirely arbitrary, but it serves to express the estimates as roughly made.

The last three columns of the table contain the nitrogen statistics. It will be observed that in every case there was a gain of nitrogen, though in several instances this gain is slight. The total gain by the twenty-seven plants growing in the case was about one-fourth of a gram; an average of nine milligrams per plant. The largest gains were generally in the instances where either the root development and that of the tubercles were both "good," or else one was "good" and the other was "fair." In other words, the gain of nitrogen was larger or smaller as the tubercles were well or poorly developed.

The results of these experiments confirm those of the earlier ones here, and at the same time justify the assumption which we had previously made that the increase of nitrogen found in the plants was due not so much to compounds of nitrogen in the atmosphere as to the fact that the plants acquired the free nitrogen of the air. Whether the plants are entirely dependent upon their roots for this acquisition from the air or whether a part at least may be obtained through their foliage is a question not yet settled. It is hoped that the pressure of other work may be in so far removed as to permit in the not distant future the carrying out of plans which have been matured for the study of this and collateral questions.

SUMMARY.

Pea plants were grown in an atmosphere freed from all nitrogen compounds. The nutritive solutions supplied all necessary mineral constituents. Carbon dioxide was added as needed. No compounds of nitrogen were supplied either in the air, soil or nutritive solution. The plants were inoculated with soil infusions, and all developed root tubercles. The twenty-seven plants made a total gain of about one-fourth a gram of nitrogen, or an average gain of nine milligrams per plant. The free nitrogen of the air was alone available to the plants, and the gain must have been by the acquisition of free nitrogen.

RESULTS OF ANALYSES OF FODDERS AND FEEDING STUFFS.

BY CHAS. D. WOODS.

In connection with the work of the Station, analyses of the following miscellaneous feeding stuffs have been made by the Station chemists. For the most part the analyses were made in connection with feeding experiments or experiments upon the growth of plants, and were in no case undertaken merely to increase the amount of this class of data. The methods of analysis recommended by the Association of Agricultural Chemists were employed.

The results of the analyses calculated to water content at harvest or at the time of analysis are given in table 2, page 28, which follows the description of samples. In this table the materials are grouped according to their water content at time of taking samples as follows: Green fodders; roots and ensilage; field cured hay, fodder and straw; cured hay and fodder; grain; and milling products. This order is also observed in the description of samples.

The results calculated to water-free (dry matter) basis are given in table 3, page 32. In this table the different species and varieties are grouped together regardless of their moisture condition at time of sampling in the following order: Grasses, straw, legumes, grain, and milling products.

The potential energy, or fuel value, of a pound of each of the feeding stuffs as given in the tables was obtained by multiplying the number of hundredths of a pound of protein and of carbohydrates by 18.6 and the number of hundredths of a pound of fat by 42.2 and taking the sum of these three products as the number of Calories of potential energy in the materials.*

DESCRIPTION OF SAMPLES.

In the description of samples the specimens are arranged in the same order as in table 2, as follows:—Green fodders; roots and ensilage; field cured hay, fodder and straw; cured hay and fodder; grain, and milling products.

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*See article on the Fuel Value of Feeding Stuffs, Report of this Station, 1890, pp. 174 to 181.

GREEN FODDERS.

1000 to 1003, *Orchard Grass (Dactylis glomerata).*—Grown by the Station in 1891. At the time of taking samples the seeds were just beginning to form. No. 1001 was from a plot without fertilizers. No. 1000 was from a plot supplied with dissolved bone-black at the rate of 320 pounds per acre and with muriate of potash at the rate of 160 pounds. No. 1002 was from a plot which, in addition to the minerals of 1000, had nitrate of soda at the rate of 160 pounds per acre. No. 1003 was from a plot which, in addition to the minerals of 1000, received nitrate of soda at the rate of 480 pounds per acre.

1004 to 1007, *Timothy (Phleum pratense).*—Grown by the Station in 1891. At time of taking sample the timothy was just beginning to bloom. No. 1005 was grown without the use of fertilizers. No. 1004 was from a plot to which there were applied dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. No. 1006 was from a plot which had the same mineral fertilizers as 1004 and, in addition, received nitrate of soda at the rate of 160 pounds per acre. No. 1007 was grown on a plot to which mixed minerals were applied as in 1004 and had, in addition, 480 pounds of nitrate of soda per acre.

1024 and 1025, *Hungarian Grass (Setaria Italica).*—Grown by the Station in 1891. No. 1024 was taken while in early bloom and contained a few weeds. No. 1025 was past full bloom when the sample was taken. The crop was affected by drouth and did not seem to have made a normal growth.

1072, *Hungarian Grass (Setaria Italica).*—Grown by the Station in 1892. The grass was a little past full bloom and seed was beginning to form when the sample was taken.

1015, *Wheat Fodder.*—Grown by the Station in 1891. At time of cutting it was three feet tall and in bloom. The yield was light.

1052 and 1053, *Wheat Fodder.*—Grown by the Station in 1892. No. 1052 had heads one-third to one-half grown. No. 1053 was in bloom and had made a heavy growth.

1023, *Red Clover (Trifolium pratense).*—Clover rowen grown by the Station in 1891. It included a little timothy. At time of cutting the clover was in bloom and beginning to form seed.

1028, *Red Clover (Trifolium pratense).*—Clover rowen grown in 1891 and consisted approximately of about one-fourth timothy and three-fourths clover. At time of cutting the clover was in early bloom; the timothy showed a few heads.

1112, *Red Clover (Trifolium pratense).*—Clover rowen grown in 1892. At time of taking sample it was past full bloom and seed was beginning to form.

1113, *Scarlet Clover (Trifolium incarnatum).*—Grown by the Station in 1892. It was sown early in the spring. The sample was taken at the beginning of October, at which time it was generally seeded, but was still growing vigorously by sending up shoots from below. The sample contained a few weeds.

1022, *Cow Pea (Dolichos sinensis).*—Grown by the Station in 1891. The peas were generally in bloom and a few imperfectly developed pods and seeds had formed.

1114, *Cow Pea (Dolichos sinensis).*—Grown by the Station in 1892. At time of taking sample the peas were about fully grown, but were not seeded.

1014, *Oat and Pea Fodder.*—Grown by the Station in 1891 on land fertilized with stable manure. At time of taking sample the oats were in bloom; a few beginning to seed.

1070 and 1071, *Oat and Pea Fodder.*—Grown by the Station in 1892. The peas in each case had formed a few seeds; the oats were in full bloom.

1026, *Oat and Vetch Fodder.*—Grown by the Station in 1891 on land that was fertilized with stable manure. At time of taking the sample the oats were beginning to form seed; the vetch was in bloom.

1029, *Barley and Pea Fodder.*—Grown by the Station in 1891. Sample was taken October 25, at which time the barley was generally headed. The peas were in early bloom. Owing to the warm, dry fall, neither the barley nor the peas appeared to make a normal growth, and the yield was light.

ROOTS AND ENSILAGE.

963, *Mangolds.*—Grown in Connecticut in 1890. Analyzed in January, 1891.

966, *Corn Ensilage.*—The ensilage was quite acid, 100 grams containing free acid equal to 125 milligrams ammonia.

FIELD CURED HAY AND FODDERS.

1017 to 1020, *Corn Stover.*—Grown by the Station in 1891 with different fertilizers. No. 1017 was grown without the use of fertilizers. No. 1018 was from a plot to which dissolved bone-black was applied at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. No. 1019 was from a plot which had the same mineral fertilizers as 1018 and in addition received nitrate of soda at the rate of 160 pounds per acre. No. 1020 was grown on a plot to which mixed minerals were applied as in 1018, and had in addition 480 pounds of nitrate of soda per acre.

1097 to 1108, *Oat Straw.*—From special nitrogen experiment conducted by the Station at Wapping in 1892. Nos. 1097 and 1098 were grown without the use of fertilizers. Nos. 1099, 1100, 1101, and 1102 were grown upon plots to which there were applied dissolved bone-black at the rate of 320 pounds per acre, and muriate of potash at the rate of 160 pounds. Nos. 1103, 1104, and 1105 were from plots grown with the same mineral fertilizers as the preceding, but had in addition 160, 320 and 480 pounds of nitrate of soda per acre respectively. Nos. 1106, 1107, and 1108 were grown upon plots to which were applied the mixed minerals, and in addition dried blood at the rate of 200, 400 and 600 pounds per acre respectively.

990 to 999, *Hay from Mixed Grasses.*—Grown by the Station in a special nitrogen experiment in 1891. Nos. 990 and 991 were grown without the use of fertilizers. Nos. 992 and 993 were grown upon plots to which were applied dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. The crop from these plots contained a larger percentage of clover than did the others. Nos. 994, 995 and 996 were grown upon plots to which was applied in addition to the mixed minerals of the preceding, nitrate of soda at the rate of 160, 320 and 480 pounds per acre. Nos. 997, 998 and 999 were grown upon plots which had in addition to the mixed minerals, sulphate of ammonia at the rate of 120, 240 and 360 pounds per acre respectively.

1054 to 1059, *Hay from Mixed Grasses.*—Grown by the Station in 1892, and were from the same experimental field as the above samples, which were grown in 1891. No. 1054 was from the same plot as 990 above, 1055 from the same plot as 992, 1056 from the same plot as 994, 1057 from the same plot as 995, and 1058 from the same plot as 996. The plots had the same treatment as in 1891. No. 1059 was from the same plot as 1055, but was carefully selected so as not to contain any clover.

CURED HAY AND FODDERS.

1044 to 1047, *Orchard Grass (Dactylis glomerata).*—Grown by the Station in 1892 and from the same plots from which were taken samples 1000 to 1003. No. 1044 was grown without the use of fertilizers. No. 1045 was from a plot to which were applied dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. No. 1046 and 1047 had, in addition to the mixed minerals, sulphate of ammonia at the rate of 120 and 360 pounds per acre respectively.

1060 to 1063, *Timothy (Phleum pratense).*—Grown by the Station in 1892, on the same plots from which samples 1004 to 1007 were taken in 1891. No. 1060 was grown without the use of fertilizers. No. 1061 had the same mineral fertilizers as 1045 above, and 1062 and 1063 were from plots which were treated in the same way as 1046 and 1047 above.

969, 973, 974, and 977 *Timothy and Red-top Hay.*—Grown in Connecticut in 1890, and analyzed during the following winter.

1040 and 1041, *Timothy and Red-top Hay.*—Grown in 1891 and analyzed in the following winter. There were small percentages of grasses other than timothy and red-top.

1021 and 1027, *Tall Red-top (Agrostis vulgaris major).*—Grown by the Station in 1891. No. 1021 was from a plot which received dissolved bone-black at the rate of 320 pounds per acre, muriate of potash at the rate of 160 pounds, and nitrate of soda at the rate of 160 pounds per acre. No. 1027 received in addition to the mixed minerals of 1021 nitrate of soda at the rate of 480 pounds per acre.

1064 and 1065, *Tall Red-top (Agrostis vulgaris major).*—Grown by the Station in 1892, on the same plots from which samples 1021 and 1027 were taken in the preceding year. They were in bloom at time of taking sample. The plots received the same mineral fertilizers as in 1891. The plot from which 1064 was taken received in addition to the mineral fertilizers 120 pounds of sulphate of ammonia per acre, and 1065, 360 pounds of sulphate of ammonia.

1066 and 1067, *Smaller Red-top (Agrotis vulgaris minor).*—Grown by the Station in 1892. In bloom at time of taking sample. No. 1066 was from a plot which received dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds, and sulphate of ammonia at the rate of 120 pounds per acre. No. 1067, in addition to the same mixed minerals as 1066, received sulphate of ammonia at the rate of 360 pounds per acre.

1012 and 1013, *Fowl Meadow Grass* (*Poa serotina*).—Grown by the Station in 1891. In bloom at time of taking sample. They were from plots to which, in addition to dissolved bone-black at the rate of 320 pounds per acre, and muriate of potash at the rate of 160 pounds, nitrate of soda was applied at the rate of 160 and 480 pounds per acre respectively.

1008 and 1009, *Rye Grass (Lolium peren).*—Grown by the Station in 1891. Just past bloom at time of cutting. The plot from which 1008 was taken received the same treatment as 1012, and 1009 the same as 1013 above.

1010 and 1011, *Meadow Fescue (Festuca elatior).*—Grown by the Station in 1891. Seed beginning to form at time of taking sample. The plot from which 1010 was taken received in addition to the mixed minerals, nitrate of soda at the rate of 160 pounds per acre, and that from which 1011 was taken, nitrate of soda at the rate of 420 pounds per acre.

1050 and 1051, *Kentucky Blue Grass (Poa pratensis).*—Grown by the Station in 1892. In milk at time of taking sample. The plots received dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160, and in addition, that of 1050 had 120 and 1051 360 pounds of sulphate of ammonia.

1048 and 1049, *Oat Grass (Avena elatior).*—Grown by the Station in 1892. In milk at time of taking sample. The plots upon which these were grown received mixed minerals as 1050 and 1051, and in addition that of 1048 received sulphate of ammonia at the rate of 120 pounds per acre, and 1049 at the rate of 360 pounds per acre.

1068 and 1069, *Brome Grass (Bromus tectorum).*—Grown by the Station in 1892. Seed beginning to form at time of taking sample. The plot from which 1068 was taken received in addition to the mixed minerals, 120 pounds of sulphate of ammonia per acre, and that of 1069 received 360 pounds of sulphate of ammonia.

1109 to 111, *Hungarian (Setaria Italica).*—These were grown by the Station in 1892, and were in full bloom at time of taking sample. No. 1109 was grown upon a plot which received dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. It made small growth, was yellowish in color, and about 6 to 10 inches in height at time of cutting. No. 1110 was grown upon a plot which received, in addition to the same mixed minerals as 1109, sulphate of ammonia at the rate of 120 pounds per acre. There was a medium growth and of fair color. No. 1111 was from a plot which received, in addition to the same mixed minerals as 1109, 360 pounds of sulphate of ammonia per acre. It made good growth and had good color.

971, 972, 975 and 976, *Rowen Hay.*—Grown in 1890 in Connecticut.

1042 and 1043, *Oat and Vetch Hay.*—Grown by the Station in 1892.

FIELD CURED GRAIN.

1030 to 1033, *Corn.*—These samples were from the same plots from which were taken the samples of stover, 1017 to 1020.

1073 to 1084, *Oats.*—Grown in a soil test experiment by the Station in 1892. 1073, 1074, and 1075 were grown without the addition of fertilizers. The plot from which 1076 was taken, received nitrate of soda at the rate of 320 pounds per acre; that of 1077 dissolved bone-black at the rate of 320 pounds per acre; 1078, muriate of potash at the rate of 160 pounds per acre; 1079, 160 pounds of nitrate of soda and 320 pounds of dissolved bone-black per acre; 1080, 160 pounds of nitrate of soda and 160 pounds of muriate of potash; 1081 received 320 pounds of dissolved bone-black and 160 pounds of muriate of potash; 1082 received 160 pounds of nitrate of soda, 320 pounds of dissolved bone-black and

160 pounds of muriate of potash per acre. No. 1083 was from a plot which received 6 tons of stable manure and 160 pounds of dissolved bone-black, and 1084 was from a plot which received 8 tons of stable manure per acre.

1085 to 1096, *Oats.*—This was from a special nitrogen experiment conducted at Wapping in 1892, the same from which the samples of oat straw, 1097 to 1108, were taken. No. 1085 was from the same plot as 1097, 1086 the same as 1098, 1087 the same as 1099, 1088 the same as 1100, 1089 the same as 1101, 1090 the same as 1102, 1091 the same as 1103, 1092 the same as 1104, 1093 the same as 1105, 1094 the same as 1106, 1095 the same as 1107 and 1096 was from the same plot as 1108.

MILLING PRODUCTS.

978, 982 and 983, 1036 and 1037, *Corn Meal.*—Western grown.

987 and 988, *Corn Meal.*—From corn grown by the Station in 1890.

984, 986, 989, 1038 and 1039, *Wheat Bran.*—From the West.

962, 979, 981, *Buckwheat Middlings.*—Purchased in the autumn of 1891 from the Rockdale Mills, Massachusetts.

1016, 1034 and 1035,—*New Process Linseed Meal.*

TABLE 2.

Proximate Composition of Fodders and Feeding Stuffs.—Results of Analyses Herewith Reported Calculated to Water Content at Time of Taking Sample.

Lab. No.	KIND.*	Water.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Pot'nl En'gy.
	Green Fodders.	%	%	%	%	%	%	Calor's per lb.
1000	Orchard grass, -	68.78	2.98	1.45	14.12	9.65	3.02	560
1001	Orchard grass, -	66.60	2.80	1.81	15.00	10.81	2.98	605
1002	Orchard grass, -	67.02	2.88	1.50	14.61	10.83	3.16	590
1003	Orchard grass, -	71.68	2.72	1.40	12.73	8.73	2.74	510
	Average, - -	**68.52**	**2.85**	**1.54**	**14.11**	**10.00**	**2.98**	**565**
1004	Timothy, - -	71.15	2.61	.85	13.98	9.17	2.24	515
1005	Timothy, - -	70.66	2.70	.86	14.40	9.19	2.19	525
1006	Timothy, - -	70.45	2.69	1.12	13.86	9.74	2.14	535
1007	Timothy, - -	71.77	2.95	1.02	13.57	8.78	1.91	515
	Average, - -	**71.01**	**2.74**	**.96**	**13.95**	**9.22**	**2.12**	**525**
1024	Hungarian grass, -	72.74	2.55	.77	14.13	7.74	2.07	450
1025	Hungarian grass, -	72.74	3.30	.78	12.65	7.86	2.67	475
1072	Hungarian grass, -	71.50	3.08	.90	13.26	9.12	2.14	515
	Average, - -	**72.33**	**2.98**	**.81**	**13.35**	**8.24**	**2.29**	**490**
1015	Wheat fodder, -	69.92	3.69	1.03	14.73	9.01	1.62	550
1052	Wheat fodder, -	76.18	2.58	.91	12.50	6.30	1.53	440
1053	Wheat fodder, -	74.25	2.19	.96	12.89	8.13	1.58	475
	Average, - -	**73.45**	**2.82**	**.97**	**13.37**	**7.81**	**1.58**	**490**
1023	Red clover, - -	70.19	5.98	1.41	13.60	6.70	2.12	550
1028	Red clover, - -	81.33	3.73	.86	8.01	4.33	1.74	335
1112	Red clover, - -	75.36	4.74	.76	11.11	6.02	2.01	440
	Average, - -	**75.63**	**4.82**	**1.01**	**10.90**	**5.68**	**1.96**	**440**
1113	Scarlet clover,- -	79.55	3.09	.75	8.55	6.27	1.79	365
1022	Cow pea, - -	83.59	3.20	.38	7.76	3.28	1.79	280
1114	Cow pea, - -	88.28	2.53	.42	4.10	3.23	1.44	200
	Average, - -	**83.81**	**2.94**	**.52**	**6.80**	**4.26**	**1.67**	**280**

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* For description of samples, see page 23.

TABLE 2.—*(Continued.)*

Lab. No.	KIND.*	Water.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Pot'nl En'gy.
	Green Fodders.	%	%	%	%	%	%	Calor's per lb.
1014	Oat and pea fodder,	82.95	2.95	.63	7.35	4.73	1.39	305
1070	Oat and pea fodder,	83.77	3.54	.74	6.23	4.26	1.46	300
1071	Oat and pea fodder,	84.64	3.51	.78	5.94	3.70	1.43	285
	Average, - -	**83.79**	**3.33**	**.72**	**6.50**	**4.23**	**1.43**	**295**
1026	Oat and vetch fodder,	75.42	3.62	.71	11.75	6.47	2.03	435
1029	Barley and pea fodder,	84.12	3.03	.57	6.10	4.28	1.90	355
	Roots and Ensilage.							
963	Mangolds, - -	91.91	.98	.09	5.24	.73	1.05	135
966	Corn ensilage, -	80.99	1.70	.59	9.53	5.90	1.29	345
	Field Cured Hay and Fodders.							
1017	Corn stover, - -	32.83	4.70	1.74	34.86	20.76	5.11	1195
1018	Corn stover, - -	28.88	3.95	1.66	36.78	22.50	6.23	1245
1019	Corn stover, - -	40.11	3.93	1.19	29.54	20.32	4.91	1050
1020	Corn stover, - -	42.54	4.63	1.36	28.49	18.20	4.78	1010
	Average, - -	**36.09**	**4.30**	**1.49**	**32.42**	**20.44**	**5.26**	**1125**
1097	Oat straw, - -	16.63	4.53	2.51	37.51	33.68	5.14	1515
1098	Oat straw, - -	14.40	4.76	2.89	39.51	33.68	4.76	1575
1099	Oat straw, - -	32.43	3.25	2.03	30.07	27.95	4.27	1225
1100	Oat straw, - -	16.97	3.99	2.38	38.21	33.59	4.86	1510
1101	Oat straw, - -	13.80	3.18	2.50	39.37	35.81	5.34	1560
1102	Oat straw, - -	15.28	4.13	2.27	38.04	35.49	4.79	1540
1103	Oat straw, - -	14.17	3.60	2.14	38.68	36.71	4.70	1555
1104	Oat straw, - -	14.33	3.91	2.20	38.26	36.58	4.72	1555
1105	Oat straw, - -	13.22	5.26	2.06	37.79	36.69	4.98	1570
1106	Oat straw, - -	14.80	3.31	2.40	37.93	36.84	4.72	1555
1107	Oat straw, - -	17.28	3.62	2.26	37.49	34.67	4.68	1505
1108	Oat straw, - -	19.26	4.17	2.33	37.30	32.80	4.14	1480
	Average, - -	**16.88**	**3.98**	**2.33**	**37.51**	**34.54**	**4.76**	**1515**
990	Hay, mixed grasses,	25.23	4.81	2.52	40.81	23.23	3.40	1385
991	Hay, mixed grasses,	22.13	5.69	3.07	40.50	24.70	3.91	1450
992	Hay, mixed grasses,	26.79	4.85	2.53	39.26	22.77	3.80	1350
993	Hay, mixed grasses,	22.56	5.66	3.12	39.60	24.66	4.40	1430
994	Hay, mixed grasses,	32.41	4.69	2.47	35.34	21.64	3.45	1255
995	Hay, mixed grasses,	31.72	5.97	2.79	33.56	22.32	3.64	1270
996	Hay, mixed grasses,	33.08	6.02	2.87	33.45	21.01	3.57	1245
997	Hay, mixed grasses,	32.61	4.97	2.60	34.78	21.48	3.56	1245
998	Hay, mixed grasses,	29.81	6.14	2.86	34.91	22.22	4.06	1300
999	Hay, mixed grasses,	32.70	6.69	2.89	33.35	20.60	3.77	1250
1054	Hay, mixed grasses,	16.15	6.45	2.66	43.12	27.31	4.31	1545
1055	Hay, mixed grasses,	17.53	9.02	2.63	38.97	26.39	5.46	1495
1056	Hay, mixed grasses,	16.80	6.40	2.78	41.01	28.42	4.59	1530
1057	Hay, mixed grasses,	19.71	7.47	2.96	38.18	27.25	4.43	1485
1058	Hay, mixed grasses,	16.92	8.77	2.96	39.05	27.54	4.76	1530
1059	Hay, mixed grasses,	9.39	6.52	2.80	47.15	30.22	3.92	1680
	Average, - -	**24.10**	**6.26**	**2.78**	**38.32**	**24.48**	**4.06**	**1400**
	Cured Hay & Fodders.							
1044	Orchard grass, -	9.37	7.65	3.77	41.23	29.79	8.19	1625
1045	Orchard grass, -	8.68	7.48	3.69	40.97	30.66	8.52	1630
1046	Orchard grass, -	7.43	10.64	5.06	38.70	29.21	8.96	1675
1047	Orchard grass, -	7.91	14,27	5.02	35.27	29.11	8.42	1675
	Average, - -	**8.35**	**10.00**	**4.38**	**39.06**	**29.69**	**8.52**	**1650**

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* For description of samples, see page 23.

TABLE 2.—*(Continued.)*

Lab. No.	KIND.*	Water.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Pot'nl En'gy.
	Cured Hay & Fodders.	%	%	%	%	%	%	Calor's per lb.
1060	Timothy, - -	10.66	6.03	3.04	44.55	30.23	5.49	1630
1061	Timothy, - -	9.85	5.63	2.68	44.33	31.72	5.79	1635
1062	Timothy, - -	8.56	6.45	2.72	45.20	31.46	5.61	1660
1063	Timothy, - -	12.29	9.38	2.80	41.18	28.80	5.55	1595
	Average, - -	**10.34**	**6.87**	**2.81**	**43.82**	**30.55**	**5.61**	**1630**
969	Timothy and red-top,	9.86	8.62	2.71	42.29	31.07	5.45	1640
973	Timothy and red-top,	15.97	7.61	2.52	40.45	28.68	4.77	1530
974	Timothy and red-top,	14.31	8.25	2.53	40.65	28.92	5.34	1550
977	Timothy and red-top,	18.93	7.05	2.47	40.02	27.14	4.39	1485
1040	Timothy and red-top,	10.61	8.15	3.25	44.63	28.17	5.19	1645
1041	Timothy and red-top,	8.43	8.06	3.24	44.22	30.78	5.27	1895
	Average, - -	**13.02**	**7.96**	**2.78**	**42.04**	**29.13**	**5.07**	**1600**
1021	Red-top, tall, - -	8.11	8.09	2.78	47.30	26.43	7.29	1640
1027	Red-top, tall, - -	7.33	12.33	3.12	44.63	24.90	7.69	1655
1064	Red-top, tall, - -	11.11	6.72	2.48	44.20	29.12	6.37	1595
1065	Red-top, tall, - -	10.83	8.30	2.82	43.57	28.43	6.05	1610
	Average, - -	**9.35**	**8.86**	**2.80**	**44.92**	**27.22**	**6.85**	**1625**
1066	Red-top, smaller, -	5.62	7.91	3.21	50.05	26.22	6.99	1700
1067	Red-top, smaller, -	10.48	10.69	3.29	42.26	26.11	7.17	1610
	Average, - -	**8.05**	**9.30**	**3.25**	**46.16**	**26.16**	**7.08**	**1655**
1012	Fowl meadow grass,	10.80	10.76	2.93	37.73	29.29	8.49	1570
1013	Fowl meadow grass,	10.44	13.32	2.53	37.84	28.35	7.52	1585
	Average, - -	**10.62**	**12.04**	**2.73**	**37.79**	**28.82**	**8.00**	**1580**
1008	Rye grass, - -	10.97	11.24	2.60	43.35	24.67	7.17	1585
1009	Rye grass, - -	10.80	9.69	2.42	45.31	24.57	7.21	1580
	Average, - -	**10.88**	**10.47**	**2.51**	**44.33**	**24.62**	**7.19**	**1585**
1010	Meadow fescue, -	12.99	9.52	2.51	44.07	24.95	5.96	1565
1011	Meadow fescue, -	11.16	6.66	2.67	46.06	27.82	5.63	1610
	Average, - -	**12.08**	**8.09**	**2.59**	**45.06**	**26.39**	**5.79**	**1580**
1050	Blue grass, - -	6.63	12.03	3.77	41.92	29.40	6.25	1710
1051	Blue grass, - -	9.59	13.96	4.08	39.32	26.78	6.27	1665
	Average, - -	**8.11**	**13.00**	**3.92**	**40.62**	**28.09**	**6.26**	**1690**
1048	Avena elatior, -	10.75	9.37	2.73	40.06	30.41	6.68	1600
1049	Avena elatior, -	10.27	10.71	2.97	39.46	29.86	6.73	1615
	Average, - -	**10.51**	**10.04**	**2.85**	**39.76**	**30.13**	**6.71**	**1610**
1068	Brome grass, - -	9.34	9.64	3.43	44.85	25.59	7.15	1635
1069	Brome grass, - -	8.46	10.07	3.28	44.82	27.17	6.20	1665
	Average, - -	**8.90**	**9.85**	**3.36**	**44.84**	**26.38**	**6.67**	**1650**
1109	Hungarian, - -	9.49	5.20	2.94	47.95	27.40	7.02	1620
1110	Hungarian, - -	8.30	6.53	2.94	46.60	28.11	7.52	1635
1111	Hungarian, - -	8.27	7.29	2.88	44.37	29.77	7.42	1635
	Average, - -	**8.69**	**6.34**	**2.92**	**46.30**	**28.43**	**7.32**	**1630**
971	Rowen, - - -	15.55	14.62	3.12	37.34	23.92	5.45	1545
972	Rowen, - - -	15.12	14.80	3.13	37.07	24.02	5.86	1545
975	Rowen, - - -	14.33	14.83	3.34	37.56	23.93	6.01	1560
976	Rowen, - - -	13.44	14.50	3.19	38.17	24.51	6.19	1570
	Average, - -	**14.61**	**14.69**	**3.19**	**37.53**	**24.10**	**5.88**	**1555**
1042	Oat and vetch hay, -	16.34	10.51	2.34	35.22	28.75	6.84	1110
1043	Oat and vetch hay, -	11.85	10.40	2.61	37.98	30.36	6.80	1200
	Average, - -	**14.09**	**10.46**	**2.48**	**36.60**	**29.55**	**6.82**	**1155**
	Field Cured Grain.							
1030	Corn, - - -	10.95	9.79	5.07	71.53	1.17	1.49	1750
1031	Corn, - - -	8.80	9.92	5.34	73.13	1.31	1.50	1795

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* For description of samples, see page 23.

TABLE 2.—*(Continued.)*

Lab. No.	KIND.*	Water.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Pot'nl En'gy.
1032	Corn, - - -	14.57	9.40	5.06	68.54	1.01	1.42	1680
1033	Corn, - - -	8.56	10.86	5.72	72.03	1.29	1.54	1810
	Average, - -	**10.72**	**9.99**	**5.29**	**71.31**	**1.20**	**1.49**	**1760**
1073	Oats, - - -	12.64	13.76	5.14	56.27	9.04	3.15	1690
1074	Oats, - - -	12.90	12.89	4.92	58.76	7.31	3.22	1475
1075	Oats, - - -	13.01	11.96	4.73	57.85	9.21	3.24	1670
1076	Oats, - - -	12.38	13.42	4.94	57.61	8.67	2.98	1690
1077	Oats, - - -	11.76	12.52	4.96	58.95	8.63	3.18	1700
1078	Oats, - - -	11.18	13.10	5.12	59.51	8.04	3.05	1715
1079	Oats, - - -	12.04	12.87	5.33	59.04	7.90	2.82	1710
1080	Oats, - - -	12.45	12.97	5.05	58.00	8.59	2.94	1695
1081	Oats, - - -	12.22	12.01	4.73	58.94	8.99	3.11	1685
1082	Oats, - - -	11.91	12.83	5.09	60.20	7.24	2.73	1710
1083	Oats, - - -	12.00	12.87	4.98	59.01	8.25	2.89	1700
1084	Oats, - - -	12.92	13.17	5.19	58.79	7.18	2.75	1690
1085	Oats, - - -	15.57	13.77	5.24	56.00	6.77	2.65	1640
1086	Oats, - - -	13.69	13.53	5.59	57.47	7.04	2.68	1685
1087	Oats, - - -	15.73	13.21	5.13	56.68	6.55	2.70	1635
1088	Oats, - - -	14.99	12.49	5.35	57.20	7.24	2.73	1660
1089	Oats, - - -	14.14	13.90	5.66	58.53	5.26	2.51	1685
1090	Oats, - - -	13.24	14.92	5.57	57.77	5.86	2.64	1695
1091	Oats, - - -	18.47	13.50	4.89	54.49	6.28	2.37	1580
1092	Oats, - - -	13.22	14.21	4.81	56.97	8.20	2.59	1685
1093	Oats, - - -	14.03	14.78	4.49	55.14	8.91	2.65	1655
1094	Oats, - - -	14.31	13.29	4.86	57.18	7.63	2.73	1660
1095	Oats, - - -	13.84	13.68	4.97	57.15	7.73	2.63	1670
1096	Oats, - - -	13.64	14.74	5.11	57.43	6.55	2.53	1680
	Average, - -	**13.43**	**13.35**	**5.08**	**57.70**	**7.63**	**2.81**	**1680**
	Milling Products.							
978	Corn meal, western,	12.83	9.20	3.86	71.01	1.73	1.37	1690
982	Corn meal, western,	12.96	9.25	3.72	71.20	1.48	1.39	1680
983	Corn meal, western,	13.53	9.13	3.81	70.30	1.85	1.38	1675
1036	Corn meal, western,	16.89	9.14	3.09	67.78	1.77	1.33	1595
1037	Corn meal, western,	16.11	9.49	3.37	68.30	1.39	1.34	1615
	Average, - -	**14.46**	**9.24**	**3.57**	**69.72**	**1.64**	**1.37**	**1651**
987	Corn meal, Station,	16.27	9 68	3.73	67.14	1.82	1.36	1620
988	Corn meal, Station,	14.44	9.52	4.28	68.82	1.63	1.31	1670
	Average, - -	**15.35**	**9.60**	**4.00**	**67.98**	**1.73**	**1.34**	**1645**
984	Wheat bran, - -	11.87	15.76	4.74	51.80	10.00	5.83	1640
985	Wheat bran, - -	10.77	17.18	4.78	50.98	10.24	6.05	1660
986	Wheat bran, - -	11.93	16.95	4.92	50.63	9.53	6.04	1640
989	Wheat bran, - -	11.99	16.62	4.81	51.03	10.21	5.34	1650
1038	Wheat bran, - -	13.05	14.35	4.77	50.22	10.82	6.79	1605
1039	Wheat bran, - -	12.60	15.24	5.14	49.94	10.67	6.41	1625
	Average, - -	**12.04**	**16.01**	**4.86**	**50.77**	**10.24**	**6.08**	**1635**
962	Buckwheat middlings,	12.55	24.65	6.04	49.52	2.89	4.35	1685
979	Buckwheat middlings,	12.62	25.24	6.25	49.57	2.09	4.23	1695
980	Buckwheat middlings,	12.88	23.85	6.08	50.64	2.45	4.10	1690
981	Buckwheat middlings,	13.18	25.07	6.38	48.43	2.69	4.25	1685
	Average, - -	**12.81**	**24.70**	**6.19**	**49.54**	**2.53**	**4.23**	**1690**
1016	Linseed meal, - -	13.36	36.12	2.60	33.82	8.29	5.81	1565
1034	Linseed meal, - -	12.55	34.11	3.29	35.12	9.27	5.66	1610
1035	Linseed meal, - -	12.06	34.30	3.18	35.93	8.79	5.74	1605
	Average, - -	**12.66**	**34.84**	**3.02**	**34.96**	**8.78**	**5.74**	**1595**

*For description of samples, see page 23.

TABLE 3.

Proximate Composition of Fodders and Feeding Stuffs.—Results of Analyses Herewith Reported, Calculated to Water-Free Substance (Dry Matter).

Lab. No.	KIND.*	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Pot'nl En'gy.
·	*Grasses, Etc.*	%	%	%	%	%	Calor's per lb.
1000	Orchard grass,	9.56	4.66	45.20	30.92	9.66	1795
1001	Orchard grass,	8.37	5.42	44.90	32.37	8.94	1820
1002	Orchard grass,	8.75	4.55	44.30	32.83	9.57	1790
1003	Orchard grass,	9.62	4.93	44.96	30.82	9.67	1795
1044	Orchard grass,	8.44	4.16	45.49	32.87	9.04	1790
1045	Orchard grass,	8.19	4.05	44.86	33.57	9.33	1785
1046	Orchard grass,	11.50	5.47	41.80	31.55	9.68	1810
1047	Orchard grass,	15.50	5.45	38.30	31.61	9.14	1820
	Average,	**9.99**	**4.83**	**43.73**	**32.07**	**9.38**	**1800**
1004	Timothy,	9.06	2.94	48.46	31.78	7.76	1785
1005	Timothy,	9.19	2.93	49.09	31.32	7.47	1790
1006	Timothy,	9.12	3.78	46.90	32.96	7.24	1815
1007	Timothy,	10.44	3.62	48.07	31.12	6.75	1820
1060	Timothy,	6.75	3.40	49.87	33.84	6.14	1825
1061	Timothy,	6.25	2.97	49.17	35.18	6.43	1810
1062	Timothy,	7.06	2.98	49.43	34.41	6.12	1820
1063	Timothy,	10.69	3.19	46.95	32.84	6.33	1820
	Average,	**8.57**	**3.23**	**48.49**	**32.93**	**6.78**	**1810**
969	Timothy and red-top,	9.56	3.01	46.91	34.47	6.05	1820
973	Timothy and red-top,	9.06	2.99	48.15	34.13	5.67	1825
974	Timothy and red-top,	9.63	2.95	47.44	33.75	6.23	1810
977	Timothy and red-top,	8.69	3.05	49.36	33.48	5.42	1835
1040	Timothy and red-top,	9.12	3.64	49.92	31.51	5.81	1835
1041	Timothy and red-top,	8.81	3.54	48.28	33.61	5.76	1835
	Average,	**9.16**	**3.19**	**48.34**	**33.49**	**5.82**	**1825**
1021	Red-top, tall,	8.81	3.03	51.47	28.76	7.93	1780
1027	Red-top, tall,	13.31	3.36	48.16	26.87	8.30	1785
1064	Red-top, tall,	7.56	2.79	49.73	32.75	7.17	1790
1065	Red-top, tall,	9.31	3.16	48.87	31.88	6.78	1810
	Average,	**9.75**	**3.08**	**49.56**	**30.06**	**7.55**	**1790**
1066	Red-top, smaller,	8.38	3.40	53.03	27.78	7.41	1805
1067	Red-top, smaller,	11.94	3.68	47.20	29.17	8.01	1800
	Average,	**10.16**	**3.54**	**50.11**	**28.48**	**7.71**	**1805**
1012	Fowl meadow grass,	12.06	3.28	42.30	32.84	9.52	1760
1013	Fowl meadow grass,	14.87	2.83	42.25	31.65	8.40	1770
	Average,	**13.47**	**3.05**	**42.27**	**32.25**	**8.96**	**1765**
1008	Rye grass,	12.62	2.92	48.69	27.71	8.06	1775
1009	Rye grass,	10.87	2.71	50.79	27.54	8.09	1775
	Average,	**11.75**	**2.81**	**49.74**	**27.62**	**8.08**	**1775**
1010	Meadow fescue,	10.94	2.89	50.65	28.67	6.85	1800
1011	Meadow fescue,	7.50	3.01	51.84	31.31	6.34	1815
	Average,	**9.22**	**2.95**	**51.25**	**29.99**	**6.59**	**1810**
1050	Blue grass,	12.88	4.04	44.89	31.49	6.70	1830
1051	Blue grass,	15.44	4.51	43.49	29.62	6.94	1835
	Average,	**14.16**	**4.27**	**44.19**	**30.56**	**6.82**	**1835**
1048	Avena elatior,	10.50	3.06	44.88	34.07	7.49	1795

* For description of samples, see page 23.

TABLE 3.—*(Continued.)*

Lab. No.	KIND.*	Pro-tein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Pot'nl En'gy.
	Grasses, etc.	%	%	%	%	%	Calor's per lb.
1049	Avena elatior,	11.94	3.31	43.97	33.28	7.50	1800
	Average,	**11.22**	**3.18**	**44.42**	**33.68**	**7.50**	**1800**
1068	Bromus,	10.63	3.78	49.47	28.23	7.89	1805
1069	Bromus,	11.00	3.58	48.96	29.68	6.78	1820
	Average,	**10.82**	**3.68**	**49.21**	**28.96**	**7,33**	**1815**
1024	Hungarian,	9.37	2.81	51.83	28.39	7.60	1785
1025	Hungarian,	12.12	2.86	46.39	28.84	9.79	1750
1072	Hungarian,	10.81	3.16	46.53	31.99	7.51	1795
1109	Hungarian,	5.75	3.24	52.98	30.27	7.76	1790
1110	Hungarian,	7.13	3.21	50.81	30.65	8.20	1785
1111	Hungarian,	7.94	3.14	48.37	32.46	8.09	1784
	Average,	**8.85**	**3.07**	**49.49**	**30.43**	**8.16**	**1780**
990	Mixed grasses,	6.44	3.38	54.58	31.06	4.54	1855
991	Mixed grasses,	7.31	3.94	52.01	31.72	5.02	1860
992	Mixed grasses,	6.63	3.45	53.63	31.10	5.19	1850
993	Mixed grasses,	7.31	4.03	51.13	31.84	5.69	1850
994	Mixed grasses,	6.94	3.66	52.28	32.01	5.11	1855
995	Mixed grasses,	8.75	4.08	49.15	32.69	5.33	1860
996	Mixed grasses,	9.00	4.29	49.98	31.40	5.33	1865
997	Mixed grasses,	7.38	3.86	51.61	31.87	5.28	1855
998	Mixed grasses,	8.75	4.08	49.73	31.66	5.78	1850
999	Mixed grasses,	9.94	4.30	49.55	30.61	5.60	1860
1054	Mixed grasses,	7.69	3.17	51.43	32.57	5.14	1840
1055	Mixed grasses,	10.94	3.19	47.25	32.00	6.62	1815
1056	Mixed grasses,	7.69	3.34	49.29	34.16	5.52	1835
1057	Mixed grasses,	9.31	3.69	47.55	33.93	5.52	1845
1058	Mixed grasses,	10.56	3.57	47.00	33.14	5.73	1840
1059	Mixed grasses,	7.19	3.09	52.04	33.35	4.33	1855
	Average,	**8.24**	**3.70**	**50.51**	**32.19**	**5.36**	**1850**
1015	Wheat fodder,	12.25	3.43	48.97	29.95	5.40	1840
1052	Wheat fodder,	10.81	3.84	52.48	26.44	6.43	1830
1053	Wheat fodder,	8.50	3.71	50.07	31.59	6.13	1835
	Average,	**10.52**	**3.66**	**50,51**	**29.32**	**5.99**	**1835**
1097	Oat straw,	5.44	3.02	44.98	40.39	6.17	1815
1098	Oat straw,	5.56	3.37	46.16	39.35	5.56	1840
1099	Oat straw,	4.81	3.01	44.50	41.36	6.32	1815
1100	Oat straw,	4.81	2.87	46.02	40.45	5.85	1820
1101	Oat straw,	3.69	2.90	45.68	41.54	6.19	1815
1102	Oat straw,	4.88	2.69	44.89	41.88	5.66	1820
1103	Oat straw,	4.19	2.49	45.07	42.78	5.47	1815
1104	Oat straw,	4.56	2.57	44.66	42.70	5.51	1820
1105	Oat straw,	6.06	2.37	43.55	42.28	5.74	1810
1106	Oat straw,	3.88	2.82	44.52	43.24	5.54	1820
1107	Oat straw,	4.38	2.73	45.32	41.91	5.66	1820
1108	Oat straw,	5.17	2.88	46.20	40.62	5.13	1835
	Average,	**4.79**	**2.81**	**45.13**	**41.54**	**5,73**	**1820**
1017	Corn stover,	7.00	2.59	51.90	30.90	7.61	1780
1018	Corn stover,	5.56	2.33	51.71	31.64	8.76	1750
1019	Corn stover,	6.56	1.99	49.32	33.92	8.21	1755
1020	Corn stover,	8.06	2.36	49.59	31.67	8.32	1760
	Average,	**6.79**	**2.32**	**50.63**	**32.03**	**8,23**	**1760**

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* For description of samples, see page 23.

TABLE 3.—*(Continued.)*

Lab. No.	KIND.*	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Pot'nl En'gy.
	Grasses, etc.	%	%	%	%	%	Calor's per lb.
971	Rowen,	17.31	3.70	44.22	28.32	6.45	1830
972	Rowen,	17.44	3.69	43.67	28.30	6.90	1820
975	Rowen,	17.31	3.90	43.84	27.93	7.02	1820
976	Rowen,	16.75	3.69	44.09	28.32	7.15	1815
	Average,	**17.20**	**3.75**	**43.95**	**28.22**	**6.88**	**1825**
1023	Red Clover,	20.06	4.72	45.61	22.48	7.13	1840
1028	Red Clover,	20.00	4.62	42.89	23.20	9.29	1795
1112	Red Clover,	19.25	3.08	45.11	24.44	8.12	1780
	Average,	**19.77**	**4.14**	**44.54**	**23.37**	**8.18**	**1805**
1113	Scarlet clover,	15.13	3.66	41.83	30.62	8.76	1785
1022	Cow pea vines,	19.50	2.30	47.30	20.01	10.89	1710
1114	Cow pea vines,	21.63	3.56	34.95	27.58	12.28	1720
	Average,	**20.57**	**2.93**	**41.13**	**23.79**	**11.58**	**1715**
1014	Oat and pea fodder,	17.31	3.68	43.10	27.77	8.14	1800
1070	Oat and pea fodder,	21.81	4.56	38.38	26.28	8.97	1805
1071	Oat and pea fodder,	22.88	5.05	38.67	24.06	9.34	1805
	Average,	**20.67**	**4.43**	**40.05**	**26.03**	**8.82**	**1805**
1026	Oat and vetch fodder,	14.75	2.88	47.81	26.31	8.25	1775
1042	Oat and vetch fodder,	12.56	2.80	42.10	34.36	8.18	1775
1043	Oat and vetch fodder,	11.81	2.96	43.08	34.44	7.71	1790
	Average,	**13.04**	**2.88**	**44.33**	**31.70**	**8.05**	**1785**
1029	Barley and pea fodder,	19.06	3.58	38.40	26.98	11.98	1720
	Roots and Ensilage.						
963	Mangolds,	12.06	1.18	64.79	8.97	13.00	1645
966	Corn ensilage,	8.94	3.12	50.14	31.04	6.76	1805
	Grain.						
1030	Corn,	11.00	5.69	80.32	1.32	1.67	1965
1031	Corn,	10.88	5.85	80.19	1.44	1.64	1970
3032	Corn,	11.00	5.92	80.23	1.19	1.66	1965
1033	Corn,	11.88	6.25	78.77	1.41	1.69	1980
	Average,	**11.19**	**5.93**	**79.88**	**1.34**	**1.66**	**1970**
1073	Oats,	15.75	5.88	64.41	10.35	3.61	1930
1074	Oats,	14.81	5.65	67.46	8.39	3.69	1930
1075	Oats,	13.75	5.43	66.50	10.59	3.73	1915
1076	Oats,	15.31	5.64	65.75	9.90	3.40	1930
1077	Oats,	14.19	5.62	66.80	9.78	3.61	1925
1078	Oats,	14.75	5.76	67.01	9.05	3.43	1935
1079	Oats,	14.63	6.06	67.12	8.98	3.21	1945
1080	Oats,	14.81	5.77	66.24	9.82	3.36	1935
1081	Oats,	13.68	5.39	67.14	10.25	3.54	1925
1082	Oats,	14.56	5.78	68.34	8.22	3.10	1940
1083	Oats,	14.63	5.66	67.05	9.37	3.29	1935
1084	Oats,	15.13	5.96	67.51	8.24	3.16	1945
1085	Oats,	16.31	6.21	66.32	8.02	3.14	1950
1086	Oats,	15.68	6.48	66.58	8.16	3.10	1955
1087	Oats,	15.68	6.09	67.26	7.77	3.20	1945
1088	Oats,	14.69	6.30	67.28	8.52	3.21	1950
1089	Oats,	16.19	6.59	68.17	6.13	2.92	1960
1090	Oats,	17.19	6.42	66.59	6.75	3.05	1955
1091	Oats,	16.56	6.00	66.83	7.70	2.91	1945

*For description of samples, see page 23.

TABLE 3.—*(Continued.)*

Lab. No.	KIND.*	Pro-tein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Pot'nl En'gy.
	Grain.	%	%	%	%	%	Calor's per lb.
1092	Oats, - - - - -	16.38	5.54	65.65	9.45	2.98	1945
1093	Oats, - - - - -	17.19	5.22	64.14	10.37	3.08	1925
1094	Oats, - - - - -	15.50	5.68	66.73	8.90	3.19	1935
1095	Oats, - - - - -	15.88	5.77	66.33	8.97	3.05	1940
1096	Oats, - - - - -	17.06	5.91	66.50	7.59	2.94	1945
	Average, - - -	**15.43**	**5.87**	**66.65**	**8.80**	**3.25**	**1940**
	Milling Products.						
978	Corn meal, western, - -	10.56	4.43	81.46	1.98	1.57	1935
982	Corn meal, western, - -	10.63	4.27	81.80	1.70	1.60	1930
983	Corn meal, western, - -	10.56	4.41	81.30	2.14	1.59	1935
1036	Corn meal, western, - -	11.00	3.72	81.54	2.13	1.61	1920
1037	Corn meal, western, - -	11.31	4.02	81.41	1.66	1.60	1925
	Average, - - -	**10.81**	**4.17**	**81.50**	**1.92**	**1.60**	**1930**
987	Corn meal, Station, - -	11.56	4.45	80.19	2.18	1.62	1935
988	Corn meal, Station, - -	11.13	5.00	80.43	1.90	1.54	1950
	Average, - - -	**11.35**	**4.72**	**80.31**	**2.04**	**1.58**	**1945**
984	Wheat bran, - - -	17.88	5.37	58.76	11.37	6.62	1865
985	Wheat bran, - - -	19.25	5.36	57.14	11.47	6.78	1865
986	Wheat bran, - - -	19.25	5.58	57.49	10.82	6.86	1865
989	Wheat bran, - - -	18.88	5.46	57.99	11.60	6.07	1875
1038	Wheat bran, - - -	16.50	5.49	57.76	12.44	7.81	1845
1039	Wheat bran, - - -	17.44	5.88	57.14	12.21	7.33	1865
	Average, - - -	**18.20**	**5.52**	**57.72**	**11.65**	**6.91**	**1860**
962	Buckwheat middlings, -	28.19	6.91	56.62	3.31	4.97	1930
979	Buckwheat middlings, -	28.88	7.15	56.74	2.39	4.84	1940
980	Buckwheat middlings, -	27.38	6.98	58.13	2.81	4.70	1935
981	Buckwheat middlings, -	28.88	7.35	55.78	3.10	4.89	1945
	Average, - - -	**28.33**	**7.10**	**56.82**	**2.90**	**4.85**	**1940**
1016	Linseed meal, new process,	41.69	3.00	39.04	9.57	6.70	1805
1034	Linseed meal, new process,	39.00	3.76	40.15	10.61	6.48	1830
1035	Linseed meal, new process,	39.00	3.61	40.86	10.00	6.53	1825
	Average, - - -	**39.90**	**3.46**	**40.01**	**10.06**	**6.57**	**1820**

* For description of samples, see page 23.

SPECIAL NITROGEN EXPERIMENT ON GRASS.

BY CHAS. D. WOODS AND C. S. PHELPS.

The special nitrogen experiment on grasses reported upon in the Reports of this Station for 1890 and 1891 have been continued during the present year.

PURPOSE OF THE EXPERIMENT.

The experiment was undertaken for the purpose of studying the effect of nitrogenous fertilizers upon grass as shown by:

1. The yield of grass and hay per acre.
2. The financial results.
3. The chemical composition and feeding value of the crop.

DETAILS OF THE EXPERIMENT.

The general plan of the experiment is similar to that of the special nitrogen experiments conducted with corn, and is given at length, together with the plan of the field, in previous Reports of the Station.*

The field has a slope to the south and southwest, but not enough to occasion the washing of fertilizers from one plot to another. The plots contained one-eighth acre each, and were laid out so as to conform to the slope of the field. They are 302.5 feet long by 18 feet wide, with unfertilized strips 3 feet wide between each plot.

The soil is a medium heavy loam, and the sub-soil is slightly clayey and adhesive. The soil was in a comparatively low state of fertility, as is shown by the yield on the unmanured plots. The land is not quickly affected by drought, and appears to retain fertilizers readily. The natural drainage is good.

The field had been in grass for several years, without the application of fertilizers of any kind until 1890. The principal grasses on the field are timothy, red-top, and Kentucky blue grass, with a slight admixture of clover and some weeds. Mineral fertilizers (potash and phosphoric acid) were applied to all the manured plots and in addition nitrogen in the form of nitrate of soda, sulphate of ammonia or dried blood, at the rate of 25, 50 or 75 pounds of nitrogen per acre, was applied to all of the plots except two.

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*Report of this Station, 1890, pp. 45 and 46, and 1891, pp. 30 and 31.

This year reports are made only upon plots 0 (unmanured), 6*a* (mixed minerals), and 7, 8 and 9 (nitrate of soda).

NOTES DURING GROWTH.

Season of 1890.—The fertilizers were applied April 29th. On May 1st, there was a rainfall of .15 inches, and from the 4th to the 6th of May, the rainfall amounted to 1.8 inches. This heavy fall of rain did not produce any apparent surface flow on the field.

Notes taken one week from the date of application show that there was considerable response to the fertilizers on all the plots supplied with nitrogen, while the plots having mixed minerals only, showed very little advance over the unmanured plots. In fact, the mineral plots gained but little over the unmanured plots until two or three weeks after the fertilizers were applied.

On June 10th, it was noted that the best growth was upon the plots which had received the most nitrogen. At this date, the blue grass was in full bloom, while the timothy heads were only one-fourth to one-third grown. The crop on the mixed mineral plots appeared to be about one-third heavier than that upon the unmanured plots, and the proportion of clover was much greater than on the plots to which nitrogen had been applied.

At the time of cutting, June 25th, the principal grasses were timothy and red-top. The timothy was beginning to blossom. The heads of the red-top were about three-fourths grown. The blue grass was not as noticeable as it had been earlier, and had pretty generally seeded, and on the unmanured plots was dry and woody. Red and white clover were a little past full bloom. There was a large proportion of clover, especially of white clover, on the mixed mineral plots. The grass on the plots directly entering into the experiment was cut June 25th. A Eureka machine (center cut) was used, and the grass on the unfertilized strips between the plots was left standing until the crop on the plots was harvested. The hay was weighed and put in the barn the afternoon of the 26th.

Season of 1891.—The fertilizer was applied May 1st. On the 3d there was a rainfall of .15 inches.

Notes taken May 8th show there were but little differences between the fertilized plots. The proportion of clover was much less than in 1890.

The first differences in growth on the plots supplied with different fertilizers were noticed May 14th. On May 15th and 16th there was a heavy rain, followed by a rapid growth on all the plots.

June 1st the following notes were taken: The proportion of fine grasses greater than in 1890. The Kentucky blue grass coming into bloom on all the plots.

All the plots made slow growth during the first half of June, and at the middle of the month the Kentucky blue grass was beginning to dry and turn brown.

On June 23d, it was noted that the growth on all the plots was much improved by the heavy rain of the 18th and 19th. A dense bottom growth and an increase in the proportion of timothy were especially noted.

At the time of cutting, June 29th, the principal grasses were timothy, red-top, and blue grass. The blue grass had generally seeded, and had become dry and woody on all the plots. The timothy was coming into bloom. The red-top was nearly full grown, and much of it in bloom. The proportion of fine grasses, and especially blue grass, was greater on all the plots than in 1890. The crop from all the plots was weighed and put into the barn between 2 and 4.30 P. M., June 30th.

The grass on the unmanured strips between the plots was cut and removed several days before the crop on the plots was harvested.

Season of 1892.—This season the fertilizers were applied April 26th, with the exception of one-third of the nitrate of soda for plots 8 and 9, which was applied May 26th.

On May 10th the grasses on the nitrate of soda plots began to show the effects of the fertilizers. The growth on the mixed mineral plot was apparently not yet affected by fertilizers.

On May 19th it was noted that the grasses on nitrate of soda plots were growing rapidly, the growth being heavier and darker colored as the amount of nitrogen used increased. The growth on the mixed mineral plots was slightly better than that on the unmanured.

On June 7th it was noted that the growth on the unmanured plots was thin and spindling, being mostly Kentucky blue grass with a little timothy, 6 to 8 inches high. The grass on the nitrate of soda plots was mostly Kentucky blue grass; the proportion of blue grass being greater than in the past two seasons. The other grasses were timothy and red-top. Proportion of timothy was greatest on plots which received the most nitrogen. The growth on the mixed mineral plot (6*a*) was mostly Kentucky blue grass and red and white clover, being about half clover. The Kentucky blue grass was coming into bloom on all the plots and was in full bloom by June 10th.

At the time of cutting, June 22d, the grasses on the unmanured and mixed mineral plots were largely Kentucky blue grass, which was dry and woody, and small proportions of timothy and red-top nearly grown. The growth on the nitrate of soda plots was largely Kentucky blue grass, the proportions of the blue grass being greater than in 1890 and 1891. It was seeded, dry and woody. The timothy was coming into bloom and the red-top about three-fourths grown. The proportions of timothy were the greatest on the heavily fertilized plots 8 and 9. There was but little clover on the nitrate of soda plots. The grass on the mixed mineral plot was light and thin, being mostly Kentucky blue grass. The proportions of clover were much larger than on the other plots, being about half of the entire weight.

The grasses were cut the afternoon of June 22d. June 23d was rainy. On the 24th the crop was partially dried and cocked. It was rainy every day until June 29th, on which day the crop was harvested and sampled.

RESULTS OF THE EXPERIMENTS.

In 1891, the proportion of fine grasses, especially Kentucky blue grass, was greater than in 1890, and in 1892 the proportions are still greater. The total yields have also greatly decreased.

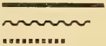
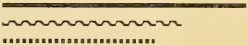
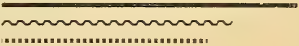
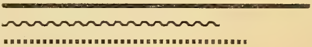
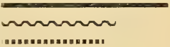
This is probably due in part to the increase of fine grasses and in part to the season. The season of 1890 was the most favorable of the three for grass. Table 4, which follows, gives the comparative yield per acre for the three seasons, 1890, 1891, 1892.

TABLE 4.

SPECIAL NITROGEN EXPERIMENT ON GRASS.

Yield of Hay per Acre.

Yield in 1890 indicated by ———, weights in Roman.
Yield in 1891 indicated by ∿∿∿∿, weights in **Fullface.**
Yield in 1892 indicated by ▪▪▪▪▪▪▪▪▪, weights in *Italics.*

No. of Plot.	FERTILIZERS.		YIELD PER ACRE. (11 % Water.)	
	Kind.	Year.	Comparative Scale.	Lbs.
0	Nothing, - -	1890		1920
		1891		**1722**
		1892		*1274*
7	Mixed Minerals, - Nitrate of Soda, - (25 lbs. Nitrogen,)	1890		4759
		1891		**3394**
		1892		*3018*
8	Mixed Minerals, - Nitrate of Soda, - (50 lbs. Nitrogen,)	1890		5874
		1891		**4505**
		1892		*4133*
9	Mixed Minerals, - Nitrate of Soda, - (75 lbs. Nitrogen,)	1890		6032
		1891		**4282**
		1892		*4696*
6a	Ds. Bone-bk. } Mx. Mur. Potash. } Min.	1890		3353
		1891		**2201**
		1892		*1980*

In the table (4) the weights as given are calculated to a uniform water basis of 11 per cent. (89 per cent. dry matter). The comparative uniformity of the yield in previous years from the unfertilized plots and those to which mixed minerals were applied indicated a fairly uniform soil. The proportions of clover were much the same in 1892 as in 1891, being small on all the plots except the mixed mineral plot. The mineral fertilizers used alone have favored the growth of clover and increased but little the growth of grasses during all three years. The application of nitrogen has favored the growth of grasses and had but little effect on the growth of clover, though the same amount of mixed minerals has been applied to all fertilized plots. It has become more evident each year that Kentucky blue grass was not a favorable grass to grow with timothy and red-top. The blue grass has been in full bloom when the other grasses were about half grown, and before the timothy and red-top were grown the blue grass had become seeded, dry, and woody.

FINANCIAL RESULTS.

Table 5, which follows, shows the kinds and amounts of fertilizers applied, their cost, the value of the increased yield, and the gain or loss per acre.

TABLE 5.

SPECIAL NITROGEN EXPERIMENT ON GRASS.

Weight and Cost of Fertilizers per Acre, Increase of Crop over that of the Nothing Plots, Value of the Increase, and Gain or Loss (–) per Acre.

Results for 1890 in Roman, for 1891 in Fullface, and for 1892 in Italics.

No. of Plot.	FERTILIZERS.	Weight of Fertilizers.	Year.	Cost of Fertilizers.	Total Crop (11 % of Water).	Increase over Nothing Plots.	Value of Increase.	Net Profit or Loss (–).
		Lbs.		$	Lbs.	Lbs.	$	$
0			1890	—	1920	—	—	—
	Nothing,	—	**1891**	—	**1722**	—	—	—
			1892	—.	*1274*	—	—	—
7	Mixed Minerals, as 6*a*,	480	1890	12.00	4759	2389	14.33	2.37
	Nitrate of Soda,	160	**1891**	**12.00**	**3394**	**1699**	**12.74**	**74**
	(25 lbs. Nitrogen,)		*1892*	*12.00*	*3018*	*1744*	*13.08*	*1.08*
8	Mixed Minerals, as 6*a*,	480	1890	15.96	5874	3504	21.02	5.10
	Nitrate of Soda,	320	**1891**	**15.96**	**4505**	**2810**	**21.08**	**5.12**
	(50 lbs. Nitrogen,)		*1892*	*15.96*	*4133*	*2859*	*21.45*	*5.49*
9	Mixed Minerals, as 6*a*,	480	1890	19.92	6032	3662	21.97	2.09
	Nitrate of Soda,	480	**1891**	**19.92**	**4282**	**2587**	**19.40**	**-.52**
	(75 lbs. Nitrogen,)		*1892*	*19.92*	*4696*	*3422*	*25.68*	*5.76*
6*a*	Dissolved Bone-black, Mix'd	320	1890	8.00	3353	983	5.90	-2.10
	Muriate of Potash, Mins.	160	**1891**	**8.00**	**2201**	**506**	**3.80**	**-4.20**
			1892	*8.00*	*1980*	*706*	*5.31*	*-2.69*

The cost of the fertilizers is taken at cash rates in ton lots for the ingredients, dissolved bone-black, potash, etc. Two dollars per ton are added to cover the cost of mixing, freight, etc. In the experiment of 1890 the hay was valued at $12 per ton, and in 1891 and 1892 at $15 per ton. In 1890 there was a fair return from the application of fertilizers where nitrogen entered into the mixture. In 1891 and 1892 there was a small gain where nitrate of soda was applied at the rate of 25 pounds of nitrogen. In each year there was a gain of about $5 per acre in the application of nitrate of soda at the rate of 50 pounds of nitrogen. In 1892 there was an equal gain in the application of nitrate of soda at the rate of 75 pounds of nitrogen per acre. In each year the mixed minerals, when used alone, were applied at a loss.

In the experiments of 1890 and 1892 there seems to have been no financial loss in the application of nitrate of soda in large quantities, as the best yield was obtained at the rate of 480 pounds (75 pounds nitrogen), but in 1891 the case seems to have been different. The yield has in general increased as the proportion of nitrogen used was increased. The limit of profit appears to be 250 to 300 pounds of nitrate of soda per acre.

CHEMICAL COMPOSITION OF THE CROP.

Immediately preceding the field weighings of the crop samples, representing as nearly as practicable the hay of each plot, were taken for analysis. Table 6 gives the results of the analysis of the crop for three years, calculated on water-free substance.

In the last column there are given the percentages of water at the time of putting the hay into the barn. It will be noted that there is a wide variation in these percentages, not only in different seasons, but in the hay from different plots of the same season. In the yield per acre, as given in tables 4 and 5, this variation in water content has been overcome by calculating the yield per acre to a uniform water basis of 11 per cent. If this had not been done, the apparent results of the experiment would have been quite different from those given in the tables, since the varying percentages of water make very great differences in the field weights of the crop. For instance, in 1890, plot 9 gave a yield as indicated by the field weight of 7344 pounds, and plot 12 of 6904 pounds, but when calculated to a uniform water content, the results are nearly identical, being 5357 pounds in case of plot 9 and 5383 pounds in case of plot 12.

TABLE 6.

SPECIAL NITROGEN EXPERIMENT ON GRASS.

Proximate Composition of Hay, Calculated on Water-free Substance.

Results for 1890 in Roman, for 1891 in Fullface, and for 1892 in Italics.

No. of Plot.	FERTILIZERS.	Year.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Water at Time of Harvest.
			%	%	%	%	%	%
0	Nothing, - - - - -	1890	7.31	3.63	52.86	31.23	4.97	21.9
		1891	**6.44**	**3.38**	**54.58**	**31.06**	**4.54**	**25.2**
		1892	*7.69*	*3.17*	*51.43*	*32.57*	*5.14*	*16.2*
7	Mixed Minerals, as 6*a*, - -	1890	8.37	3.71	48.83	33.54	5.55	26.9
	Nitrate of Soda, - - -	**1891**	**6.94**	**3,66**	**52.28**	**32.01**	**5.11**	**32,4**
	(25 lbs. Nitrogen,) - - -	*1892*	*7.69*	*3.34*	*49.29*	*34.16*	*5.52*	*16.8*
8	Mixed Minerals, as 6*a*, - -	1890	8.09	3.49	48.69	34.61	5.12	29.1
	Nitrate of Soda, - - -	**1891**	**8.75**	**4.08**	**49.15**	**32.69**	**5.33**	**31.7**
	(50 lbs. Nitrogen,) - - -	*1892*	*9.31*	*3.69*	*47.55*	*33.93*	*5.52*	*19.7*
9	Mixed Minerals, as 6*a*, - -	1890	9.19	3.51	47.59	34.55	5.16	27.0
	Nitrate of Soda, - - -	**1891**	**9.00**	**4.29**	**49.98**	**31.40**	**5.33**	**33.0**
	(75 lbs. Nitrogen,) - - -	*1892*	*10.56*	*3.57*	*47.00*	*33.14*	*5.73*	*16.9*
6*a*	Dissolved Bone-black, Mixed	1890	8.23	3.21	49.96	32.78	5.82	25.7
	Muriate of Potash, Min'als.	**1891**	**6.63**	**3.45**	**53.63**	**31.10**	**5.19**	**26.8**
		1892	*10.94**	*3.19*	*47.25*	*32.00*	*6.62*	*17.5*

It will be noted that in each year the application of the large amounts of nitrogen has increased the percentages of protein over that of the crop from the unmanured plots. The percentages of protein were larger in the crops from the mixed mineral plots than in that from the unmanured, and in 1892 the percentage of protein of the crop from the mixed mineral plot is higher than that from any of the plots to which nitrogen was applied. This, as has been pointed out in previous reports, is due to the large amount of clover which the crop from the mixed mineral plots contained. This year samples of the grasses from the mixed mineral plots were analyzed separately. The results of the analysis of the grasses from the mixed mineral plots and that of the total crop are given in the table on the next page.

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* This high percentage of protein is due to the large amount of clover in the crop from this plot. See discussion on next page.

	GRASSES FROM PLOT 6*a*.	TOTAL CROP FROM PLOT 6*a*.
Protein,	7.19	10.94
Fat,	3.09	3.19
Nitrogen-free extract,	52.04	47.25
Fiber,	33.35	32.00
Ash,	4.33	6.62

As shown in the table, the protein is nearly four per cent. less in the grasses than in the total yield. The percentage of protein in the grasses alone from the mixed mineral plot is lower than that from any of the other plots.

The variation in percentage of protein from year to year upon the same plots is difficult to account for. In 1890 a relatively larger amount of clover grew than in either of the succeeding years upon the plots to which nitrogen was applied. It was thought last year that the decrease in percentages of protein on the different plots was due to the fact that there was less clover on all the plots in 1891 than in 1890, but in 1892 the proportions of clover are still relatively as small as in 1891 on all of the plots except the mixed mineral plot, and yet the percentages of nitrogen are the highest that they have been found at all. Especially is this true on the plots (8 and 9) which have received the largest amounts of nitrogen.

In each year the effects of nitrogenous fertilizers upon the percentages of protein in the grass are quite strikingly shown The percentage of nitrogen (protein) has been considerably increased where the larger quantities of nitrogen were used. In this way the feeding value has also been increased. This two-fold use of nitrogen shows the importance of supplying grasses with abundance of this element, either in the form of stable manure, or fertilizers, like nitrate of soda, sulphate of ammonia, Peruvian guano, etc. The use of nitrate of soda in the spring at the rate of 150 to 200 pounds per acre on land which has been previously well fertilized with stable manure may be made to give profitable results.

In table 7 there are given the yield of dry matter and the approximate constituents per acre for all three years. It will be noticed that the pounds of protein removed in the crop increased much faster than the dry matter per acre. This was, of course, to have been expected from the results of the chemical analysis.

TABLE 7.

Special Nitrogen Experiment on Grass. Water-free Substance and Proximate Ingredients per Acre.

Results for 1890 in Roman, for 1891 in Fullface, and for 1892 in Italics.

No. of Plot.	FERTILIZERS.	Year.	Water-free Substance at Harvest.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0.	Nothing, - - - - - -	1890	1707	125	62	902	533	85
		1891	**1531**	**99**	**52**	**836**	**475**	**69**
		1892	*1147*	*88*	*36*	*590*	*374*	*59*
7.	Mixed Minerals, as 6*a*, - - Nitrate of Soda, (25 lbs. Nitrogen,)	1890	4230	354	157	2065	1419	235
		1891	**3017**	**209**	**110**	**1578**	**966**	**154**
		1892	*2716*	*209*	*91*	*1338*	*928*	*150*
8.	Mixed Minerals, as 6*a*, - - Nitrate of Soda, (50 lbs. Nitrogen,)	1890	5221	423	182	2542	1807	267
		1891	**4004**	**350**	**163**	**1969**	**1309**	**213**
		1892	*3720*	*346*	*137*	*1769*	*1263*	*205*
9.	Mixed Minerals, as 6*a*, - - Nitrate of Soda, (75 lbs. Nitrogen,)	1890	5357	492	188	2550	1850	277
		1891	**3806**	**342**	**163**	**1903**	**1195**	**203**
		1892	*4227*	*446*	*151*	*1987*	*1401*	*242*
6*a*.	Dissolved Bone-black, Muriate of Potash, } Mixed Minerals.	1890	2989	246	96	1493	980	174
		1891	**1956**	**130**	**67**	**1049**	**608**	**102**
		1892	*1782*	*195*	*57*	*842*	*570*	*118*

It is of interest to note the relations between the nitrogen supplied in the fertilizers and that removed by the crop during the three years in which the experiment has been conducted. It has been seen (page 41) that nitrogen when applied in the form of nitrate of soda at the rate of 50 pounds of nitrogen per acre, was used in every case at a pecuniary profit. It does not, however, necessarily follow from this that it was applied without loss of nitrogen. As shown in the table (8) which follows, about 50 pounds of nitrogen per acre were removed in the crops from the unmanured plots. During the three years on plot 7 there have been applied 75 pounds of nitrogen, and 124 pounds have been removed, or 49 pounds more were removed than were applied in the fertilizer. This is practically the same amount as that removed from the unmanured plot. On plot 9, 225 pounds of nitrogen were supplied in the fertilizer and only 205 removed in the crop.

That is, there were 20 pounds less nitrogen in the crop than were supplied in the fertilizer. If we assume that the soil of all of the plots would have furnished the same amounts of nitrogen in the crop as did the unmanured plot, then it will be seen that from plot 7 all of the nitrogen supplied was gotten back; that there were 21 pounds of nitrogen lost on plot 8, and 70 pounds on plot 9.

Plots 7, 8 and 9 had the same amount of mineral fertilizers applied as the mixed mineral plot, 6*a*. If we assume that these plots (7, 8 and 9) would have yielded with the minerals alone a crop containing equal amounts of nitrogen with that obtained from 6*a*, where the mixed minerals were used alone, it will be seen that on plot 7 there was a loss of 42 pounds of nitrogen, on plot 8 of 62, and on plot 9 of 111 pounds of nitrogen.

The above points out that even under favorable circumstances and where the fertilizer is applied at a financial advantage, plants may be able to utilize only a portion of the nitrogen which is furnished them in the fertilizer.

TABLE 8.

Amounts of Nitrogen Removed in Crops and Supplied in Fertilizers During Three Years, 1890, 1891, and 1892.

No. of Plot.	FERTILIZERS.	Total Nitrogen removed in crop.	Nitrogen supplied in fertilizers.	Nitrogen removed in excess of that supplied.	Nitrogen removed in excess of that obtained in crop from Plot 0.	Nitrogen removed in excess of that obtained in crop from Plot 6*a*.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0	Nothing, - - - - - -	50	—	50	—	—
7	Mixed Minerals, as 6*a*, - - - Nitrate of Soda, 25 lbs. Nitrogen,	124	75	49	74	33
8	Mixed Minerals, as 6*a*, - - - Nitrate of Soda, 50 lbs. Nitrogen,	179	150	29	129	88
9	Mixed Minerals, as 6*a*, - - - Nitrate of Soda, 75 lbs. Nitrogen,	205	225	−20	155	114
6*a*	Dissolved Bone-black, Muriate of Potash, } Mixed Minerals.	91	—	91	41	—

SUMMARY.

The object of this experiment is to study the effect of nitrogenous fertilizers upon grass, as shown by the yield per acre, the financial results, and the chemical composition of the hay. The plots contained one-eighth acre each, and were separated from each other by unfertilized strips. The field had been in grass for several years, and the soil was considerably reduced in fertility. Mineral fertilizers were applied to all the plots except one, which was left unmanured, and, with one exception, nitrogen was applied to the manured plots at the rate of 25, 50, and 75 pounds per acre.

THE RESULTS.

The addition of mineral fertilizers increased the yield of clover, but did not seem to increase very materially the yield of grasses.

In general the yield of hay increased with the quantity of nitrogen supplied.

The mineral fertilizers, when used alone, were applied at a financial loss.

The application of 160 pounds of nitrate of soda per acre (25 lbs. of nitrogen), in addition to the mixed minerals, gave an average profit during the three years of $1.40 per acre; 320 pounds of nitrate of soda (50 lbs. of nitrogen) gave an average profit of $5.24 per acre, and 480 pounds of nitrate of soda (75 lbs. of nitrogen) an average profit of $2.45 per acre. The returns from 320 pounds were very uniform, the profit being $5.10, $5.12 and $5 49 respectively for the three years.

The application of nitrogenous fertilizers increased the percentages of protein in the crop and somewhat in proportion to the amount of nitrogen supplied.

The increase in the amount of nitrogen in the crop did not equal the increased amount of nitrogen supplied in the fertilizers, implying that the plants were not able to utilize all the nitrogen supplied.

EFFECTS OF DIFFERENT FERTILIZERS UPON THE COMPOSITION OF OATS AND STRAW.

BY CHAS. D. WOODS.

In the Annual Report of this Station for 1890* there were given the results of the analysis of the crop of oats grown in a "special nitrogen" experiment. It was there stated that the investigation was undertaken with the hope of adding to the knowledge of the effects of different fertilizers upon the percentage composition, and upon the total yield of nutritive ingredients of grain and straw of the oat plant, with special reference to the effect of nitrogenous fertilizers upon the amounts of protein. In continuance of this work, the analyses of the oats and straw from a "special nitrogen" experiment and the grain from a "soil test" experiment with oats were undertaken the present year.

Quite large samples, representing the yield as fairly as practicable, were taken by the Station Agriculturist at the time of harvest. The oats had been cut for some time before harvesting, and were quite dry when the field weighings were made and samples taken. The crop from each plot was threshed separately at harvest, and samples were selected and weighed immediately after threshing. The methods of analyses recommended by the Association of Official Agricultural Chemists were followed.

The results of the analyses are given in the tables. A brief discussion of these results and of those of 1890 follows the tables.

SPECIAL NITROGEN EXPERIMENT.

This experiment was conducted on the farm of Mr. W. W. Green of Wapping, and is described in the article on field experiments in this Report. The field is located in the red sand-stone region of the Connecticut Valley, and has been in grass for several years without manure, and yielded less than one ton of hay per acre. The soil is a light loam with a subsoil of nearly the same character to the depth of 2 to 2½ feet.

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* Pages 93–106.

TABLE 9.

SPECIAL NITROGEN EXPERIMENT WITH OATS IN 1892.

*Proximate Composition of Water-free Substance of Oats and Oat Straw.**

Plot No.	FERTILIZERS.	Laboratory No.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Nitrogen.
	OATS.		%	%	%	%	%	%
0	Unmanured, - - - -	1085	16.31	6.21	66.32	8.02	3.14	2.61
00	Unmanured, - - - -	1086	15.68	6.48	66.58	8.16	3.10	2.51
	Average of Unmanured, -		**16.00**	**6.34**	**66.45**	**8.09**	**3.12**	**2.56**
6	Dis. Bone-black, Mixed Muriate of Potash, Minr'ls.	1087	15.68	6.09	67.26	7.77	3.20	2.51
6*a*	Mixed Minerals, as No. 6, -	1088	14.69	6.30	67.28	8.52	3.21	2.35
6*b*	Mixed Minerals, as No. 6, -	1089	16.19	6.59	68.17	6.13	2.92	2.59
6*c*	Mixed Minerals, as No. 6, -	1090	17.19	6.42	66.59	6.75	3.05	2.75
	Average of Mixed Minerals,		**15.94**	**6.35**	**67.32**	**7.29**	**3.10**	**2.55**
	Nitrate of Soda Group.							
7	Mixed Minerals, as No. 6, - Nitrate of Soda (25 lbs. N.),	1091	16.56	6.00	66.83	7.70	2.91	2.65
8	Mixed Minerals, as No. 6, - Nitrate of Soda (50 lbs. N.),	1092	16.38	5.54	65.65	9.45	2.98	2.62
9	Mixed Minerals, as No. 6, - Nitrate of Soda (75 lbs. N.),	1093	17.19	5.22	64.14	10.37	3.08	2.75
	Dried Blood Group.							
13	Mixed Minerals, as No. 6, - Dried Blood (25 lbs. N.), -	1094	15.50	5.68	66.73	8.90	3.19	2.48
14	Mixed Minerals, as No. 6, - Dried Blood (50 lbs. N.), -	1095	15.88	5.77	66.33	8.97	3.05	2.54
15	Mixed Minerals, as No. 6, - Dried Blood (75 lbs. N.), -	1096	17.06	5.91	66.50	7.59	2.94	2.73
	OAT STRAW.							
0	Unmanured, - - - -	1097	5.44	3.02	44.98	40.39	6.17	.87
00	Unmanured, - - - -	1098	5.56	3.37	46.16	39.35	5.56	.89
	Average of Unmanured, -		**5.50**	**3.19**	**45.58**	**39.87**	**5.86**	**.88**
6	Dis. Bone-black, Mixed Muriate of Potash, Minr'ls.	1099	4.81	3.01	44.50	41.36	6.32	.77
6*a*	Mixed Minerals, as No. 6, -	1100	4.81	2.87	46.02	40.45	5.85	.77
6*b*	Mixed Minerals, as No. 6, -	1101	3.69	2.90	45.68	41.54	6.19	.59
6*c*	Mixed Minerals, as No. 6, -	1102	4.88	2.69	44.89	41.88	5.66	.78
	Average of Mixed Minerals,		**4.55**	**2.87**	**45.27**	**41.31**	**6.00**	**.73**
	Nitrate of Soda Group.							
7	Mixed Minerals, as No. 6, - Nitrate of Soda (25 lbs. N.),	1103	4.19	2.49	45.07	42.78	5.47	.67
8	Mixed Minerals, as No. 6, - Nitrate of Soda (50 lbs. N.),	1104	4.56	2.57	44.66	42.70	5.51	.73
9	Mixed Minerals, as No. 6, - Nitrate of Soda (75 lbs. N.),	1105	6.06	2.37	43.55	42.28	5.74	.97
	Dried Blood Group.							
13	Mixed Minerals, as No. 6, - Dried Blood (25 lbs. N.), -	1106	3.88	2.82	44.52	43.24	5.54	.62
14	Mixed Minerals, as No. 6, - Dried Blood (50 lbs. N.), -	1107	4.38	2.73	45.32	41.91	5.66	.70
15	Mixed Minerals, as No. 6, - Dried Blood (75 lbs. N.), -	1108	5.17	2.88	46.20	40.62	5.13	.83

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* For proximate composition calculated to water content at time of harvest, see table 2, pages 28-31, of this Report.

TABLE 10.

SPECIAL NITROGEN EXPERIMENT WITH OATS IN 1892.

Proximate Ingredients Per Acre in Oats and Straw.

Plot No.	FERTILIZERS.	Laboratory No.	Water-free Oats.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
	OATS.		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0	Unmanured, - - - - -	1085	600	97	37	399	48	19
00	Unmanured, - - - - -	1086	449	70	29	299	37	14
	Average of Unmanured, -		**525**	**83**	**33**	**349**	**43**	**17**
6	Dis. Bone-black, } Mixed Muriate of Potash, } Minerals.	1087	523	82	32	351	41	17
6*a*	Mixed Minerals, as No. 6, -	1088	417	61	26	281	36	13
6*b*	Mixed Minerals, as No. 6, -	1089	515	83	34	351	32	15
6*c*	Mixed Minerals, as No. 6, -	1090	547	94	35	364	37	17
	Average of Mixed Minerals, -		**501**	**80**	**32**	**337**	**37**	**15**
	Nitrate of Soda Group.							
7	Mixed Minerals, as No. 6, - Nitrate of Soda (25 lbs. N.), -	1091	726	120	44	485	56	21
8	Mixed Minerals, as No. 6, - Nitrate of Soda (50 lbs. N.), -	1092	738	121	41	484	70	22
9	Mixed Minerals, as No. 6, - Nitrate of Soda (75 lbs. N.), -	1093	774	133	40	497	80	24
	Dried Blood Group.							
13	Mixed Minerals, as No. 6, - Dried Blood (25 lbs. N.), -	1094	626	97	35	418	56	20
14	Mixed Minerals, as No. 6, - Dried Blood (50 lbs. N.), -	1095	655	104	38	434	59	20
15	Mixed Minerals, as No. 6, - Dried Blood (75 lbs. N.), -	1096	674	115	40	448	51	20
	OAT STRAW.							
0	Unmanured, - - - - -	1097	1292	70	39	581	522	80
00	Unmanured, - - - - -	1098	933	52	32	430	367	52
	Average of Unmanured, -		**1113**	**61**	**35**	**506**	**445**	**66**
6	Dis. Bone-black, } Mixed Muriate of Potash, } Minerals.	1099	987	47	30	440	408	62
6*a*	Mixed Minerals, as No. 6, -	1100	1312	63	38	603	531	77
6*b*	Mixed Minerals, as No. 6, -	1101	1241	46	36	566	516	77
6*c*	Mixed Minerals, as No. 6, -	1102	1034	50	28	463	433	58
	Average of Mixed Minerals, -		**1144**	**51**	**33**	**520**	**472**	**68**
	Nitrate of Soda Group.							
7	Mixed Minerals, as No. 6, - Nitrate of Soda (25 lbs. N.), -	1103	1802	76	45	811	771	99
8	Mixed Minerals, as No. 6, - Nitrate of Soda (50 lbs. N.), -	1104	1885	86	48	842	805	104
9	Mixed Minerals, as No. 6, - Nitrate of Soda (75 lbs. N.), -	1105	2994	181	71	1304	1266	172
	Dried Blood Group.							
13	Mixed Minerals, as No. 6, - Dried Blood (25 lbs. N.), -	1106	1712	67	48	762	740	95
14	Mixed Minerals, as No. 6, - Dried Blood (50 lbs. N.), -	1107	2134	93	58	967	895	121
15	Mixed Minerals, as No. 6, - Dried Blood (75 lbs. N.), -	1108	2140	110	62	989	869	110

TABLE 11.

SPECIAL NITROGEN EXPERIMENT WITH OATS IN 1892.

Yield Per Acre in Pounds.

Plot No.	Fertilizers.	Weight of One Bushel of Oats.	Harvest Weights.		Weights from Analyses. Oats and Straw.			
			Oats.	Straw.	Water-free Substance.	Protein.	Fat.	Nitrogen-free Extract.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0	Unmanured,	27.7	710	1550	1892	167	76	979
00	Unmanured,	28.7	520	1090	1382	122	61	730
	Average of Unmanured,	**28.2**	**615**	**1320**	**1637**	**145**	**68**	**855**
6	Dis. Bone-black, Mixed Muriate of Potash, Min'ls	26.1	620	1460	1510	129	62	790
6*a*	Mixed Minerals, as 6,	27.5	490	1580	1729	124	64	884
6*b*	Mixed Minerals, as 6,	27.8	600	1440	1756	129	70	918
6*c*	Mixed Minerals, as 6,	28.8	630	1220	1581	144	63	828
	Average of Mixed Minerals,	**27.6**	**585**	**1425**	**1644**	**131**	**65**	**855**
	Nitrate of Soda Group.							
7	Mixed Minerals, as 6, Nitrate of Soda (25 lbs. N.),	29.1	890	2100	2528	196	89	1297
8	Mixed Minerals, as 6, Nitrate of Soda (50 lbs. N.),	28.3	850	2200	2623	207	89	1326
9	Mixed Minerals, as 6, Nitrate of Soda (75 lbs. N.),	25.7	900	3450	3768	314	111	1800
	Dried Blood Group.							
13	Mixed Minerals, as 6, Dried Blood (25 lbs. N.),	29.2	730	2010	2338	164	83	1179
14	Mixed Minerals, as 6, Dried Blood (50 lbs. N.),	29.7	760	2580	2789	197	96	1401
15	Mixed Minerals, as 6, Dried Blood (75 lbs. N.),	29.0	780	2650	2814	225	102	1436

From the figures in table 10 it will be noticed that the average yield of water-free oats was 24 pounds greater on the unmanured than on the plots to which mixed minerals (phosphoric acid and potash) were applied, and that the yield of water-free straw was 31 pounds less on the unmanured. This means that the total yield (see table 10) of water-free substance (dry matter) averaged nearly the same on the unmanured plots as on those supplied with minerals. From this it might seem that the soil was not in special need of mineral fertilizers and that the increased yield on the plots supplied with mixed minerals and different quantities of nitrogen was due to the action of the nitrogen. The "soil test" portion of the experiment was omitted, and hence it is not possible from the data to say that the above conclusion may not be correct, but since the yield of oats in plot 7 was increased 225 pounds over that of the mixed mineral plots, and the yield of oats in plots 8 and 9 were only 12 and 44 pounds respectively greater than the yield on plot 7, it seems hardly probable that all of this great increase of 225 pounds could have been due to the nitrogen alone. It is more probable that the soil was deficient in all three of the chief constituents of plant food, and that the application of any one or two would not have produced any very marked difference in yield. The more readily available nitrogen of the nitrate seems to have given better returns than did the same quantities of organic nitrogen applied in the form of dried blood. The relation between the amounts of nitrogen applied in the fertilizers and that found in the crop is discussed on page 54 beyond.

SOIL TEST EXPERIMENT.

This experiment was carried out on the Station land, and was the third crop in a rotation soil test experiment.* The field was planted to corn in 1890, potatoes in 1891, and to oats this year (1892), the order of the plots and the fertilizers used being the same each season.

The plots were seeded with common Western oats at the rate of two and one-half bushels per acre. The seeds germinated well and there was a fairly uniform stand. The crop throughout the season on the plots to which nitrogen had been applied in the fertilizer was in advance of that upon the plots upon which no nitrogen was used. The application of phosphoric acid in the fertilizer appeared to hasten the maturity of the crop. The oats grown on the plots to which phosphoric acid was applied were also heavier, *i. e.*, weighed more per bushel.

Table 12, on the following page, gives the results of the analyses of the grain from each plot entering into the experiment, and the total yield per acre of the nutritive ingredients of the crop.

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* Report of this Station, 1890, pp. 69–71; 1891, pp. 81–183, and this Report in article on Field Experiments beyond.

TABLE 12.

SOIL TEST EXPERIMENT WITH OATS IN 1892.

*Proximate Composition of Water-free Substance of Oats and Proximate Ingredients per Acre in Oats.**

Plot No.	FERTILIZERS.	Laboratory No.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Nitrogen.
	Composition.		%	%	%	%	%	%
0	Unmanured, - - -	1073	15.75	5.88	64.41	10.35	3.61	2.52
00	Unmanured, - - -	1074	14.81	5.65	67.46	8.39	3.69	2.37
000	Unmanured, - - -	1075	13.75	5.43	66.50	10.59	3.73	2.20
	Average of Unmanured,		**14.77**	**5.65**	**66.12**	**9.78**	**3.68**	**2.36**
A.	Nitrate of Soda, - -	1076	15.31	5.64	65.75	9.90	3.40	2.45
B.	Dissolved Bone-black, -	1077	14.19	5.62	66.80	9.78	3.61	2.27
C.	Muriate of Potash, - -	1078	14.75	5.76	67.01	9.05	3.43	2.36
D.	Nitrate of Soda, - - Dissolved Bone-black, -	1079	14.63	6.06	67.12	8.98	3.21	2.34
E.	Nitrate of Soda, - - Muriate of Potash, - -	1080	14.81	5.77	66.24	9.82	3.36	2.37
F.	Dissolved Bone-black, - Muriate of Potash, - -	1081	13.68	5.39	67.14	10.25	3.54	2.19
G.	Dissolved Bone-black, - Muriate of Potash, - - Nitrate of Soda, - -	1082	14.56	5.78	68.34	8.22	3.10	2.33
X.	Stable Manure, - -	1083	14.63	5.66	67.05	9.37	3.29	2.34
Y.	Dissolved Bone-black, - Stable Manure, - -	1084	15.13	5.96	67.51	8.24	3.16	2.42
	Yield.		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
0	Unmanured, - - -	1073	124	46	506	81	28	—
00	Unmanured, - - -	1074	98	37	444	55	24	—
000	Unmanured, - - -	1075	88	35	424	67	24	—
	Average of Unmanured,		**103**	**39**	**458**	**68**	**25**	—
A.	Nitrate of Soda, - -	1076	145	53	622	93	32	—
B.	Dissolved Bone-black, -	1077	108	43	509	75	27	—
C.	Muriate of Potash, - -	1078	104	41	471	64	24	—
D.	Nitrate of Soda, - - Dissolved Bone-black, -	1079	157	65	719	96	34	—
E.	Nitrate of Soda, - - Muriate of Potash, - -	1080	125	49	557	83	28	—
F.	Dissolved Bone-black, - Muriate of Potash, - -	1081	109	43	534	81	28	—
G.	Dissolved Bone-black, - Muriate of Potash, - - Nitrate of Soda, - -	1082	162	64	759	91	34	—
X.	Stable Manure, - -	1083	164	63	751	105	37	—
Y.	Stable Manure, - - Dissolved Bone-black, -	1084	180	71	804	98	38	—

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* For proximate composition calculated to water content at harvest, see table 2, pp. 29 and 31, of this Report.

COMPOSITION OF THE OATS.

In the table which follows there is given the average composition of the oats, calculated to water-free substance, as found by analysis in the special nitrogen experiments of 1890 and 1892 and in the soil test experiment of 1892. There are also given the minimum and maximum percentages of each of the constituents. There are also appended the results of the analyses of other New England grown oats and the composition of American oats as shown by the average of all the analyses that have been made.

TABLE 13.

Percentage Composition of Water-free Substance of Oats.

	Protein.	Fat.	Nit.-free Extract.	Fiber.	Ash.
Special Nitrogen Experiment, 1890.	%	%	%	%	%
Minimum, - - - - - - - -	13.1	5.5	62.4	10.1	2.7
Maximum, - - - - - - - -	16.3	6.2	65.2	16.0	3.4
Average of all, - - - - - - - -	14.7	5.9	64.0	12.5	2.9
Average grown with nitrogenous fertilizers, -	15.1	6.0	64.5	11.6	2.8
Special Nitrogen Experiment, 1892.					
Minimum, - - - - - - - -	14.7	5.2	66.3	6.1	2.9
Maximum, - - - - - - - -	17.2	6.6	68.2	10.4	3.2
Average of all, - - - - - - - -	16.2	6.0	66.5	8.2	3.1
Average grown with nitrogenous fertilizers, -	16.4	5.7	66.1	8.8	3.0
Soil Test Experiment, 1892.					
Minimum, - - - - - - - -	13.7	5.4	64.4	8.2	3.1
Maximum, - - - - - - - -	15.8	6.0	68.3	10.6	3.7
Average of all, - - - - - - - -	14.7	5.7	66.8	9.4	3.4
Average grown with nitrogenous fertilizers, -	14.8	5.8	67.0	9.1	3.3
All other (9) Analyses of New England Grown Oats.					
Minimum, - - - - - - - -	9.1	4.9	67.3	9.9	2.9
Maximum, - - - - - - - -	13.4	6.1	70.8	14.7	4.0
Average, - - - - - - - - -	11.1	5.7	68.8	11.0	3.4
*All other (30) Analyses of American Oats.**					
Average, - - - - - - - - -	13.2	5.6	67.0	10.8	3.4

* Compilation of American Feeding Stuffs.—Jenkins and Winton.

The high percentages of protein in the oats from these experiments, even in those from the unfertilized plots, are very noticeable. In the special nitrogen experiment of 1890, the grain in most cases was not very well developed, and for the most part the oats were very light, the heaviest weighing 31.7 pounds per bushel. The crop from this year's experiments was considerably heavier.

It will be observed that the percentages of the fiber were greater in the oats of the 1890 experiment than in this year's. This would seem to confirm the suggestion made in the Report of 1890 that a high percentage of fiber, together with a low weight of oats per bushel, indicates an inferior quality of oats. In the experiment of 1890 there was a definite relation between the weight of oats and the percentages of fiber. Light weight oats in that experiment uniformly gave high percentages of fiber. This definite relation does not hold in the experiments of 1892, and is probably not true for heavy, well developed oats. In some cases in this year's experiments the oats which contained the largest percentages of fiber were the heaviest per bushel.

TABLE 14.

RELATION BETWEEN NITROGEN APPLIED IN FERTILIZERS AND PROTEIN (NITROGEN × 6.25) FOUND IN CROP.

Percentages of Protein in Water-free Substance of Oats and of Straw.

FERTILIZERS.	OATS.			STRAW.		
	Nitrate of Soda Group.	Sulp. of Ammonia Group.	Dried Blood Group.	Nitrate of Soda Group.	Sulp. of Ammonia Group.	Dried Blood Group.
Mixed Minerals and—	%	%	%	%	%	%
25 lbs. Nitrogen, 1890, -	15.7	13.9	14.5	5.1	5.7	5.6
25 lbs. Nitrogen, 1892, -	16.6	—	15.5	4.2	—	3.9
Average, - - - -	**16.2**	—	**15.0**	**4.7**	—	**4.8**
50 lbs. Nitrogen, 1890, -	16.3	15.1	14.1	5.3	6.8	5.3
50 lbs. Nitrogen, 1892, -	16.4	—	15.9	4.6	—	4.4
Average, - - - -	**16.4**	—	**15.0**	**5.0**	—	**4.9**
75 lbs. Nitrogen, 1890, -	16.8	15.0	14.7	6.0	7.5	5.4
75 lbs. Nitrogen, 1892, -	17.2	—	17.1	6.1	—	5.2
Average, - - - -	**17.0**	—	**15.9**	**6.1**	—	**5.3**

The above table shows that the percentages of protein in both the oats and the straw in each experiment increased, as a rule, with the increased application of nitrogen in the fertilizer. It will also be observed that, as a rule, the most marked advance in the percentages of protein was found where the largest applications of nitrogen were made. That is, the percentages of protein increased in a greater ratio than the increase in amount of nitrogen in the fertilizer. The third 25 pounds of nitrogen seemed to affect the percentage of protein more than the second 25 pounds did.

TABLE 15.

Pounds of Protein per Acre in Crop.

FERTILIZERS.	OATS.			STRAW.			OATS & STRAW		
	Nit. of Soda Group.	Sulp. of Am. Group.	Dried Blood Group.	Nit. of Soda Group.	Sulp. of Am. Group.	Dried Blood Group.	Nit. of Soda Group.	Sulp. of Am. Group.	Dried Blood Group.
Mixed Minerals and—	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
25 lbs. Nitrogen, 1890, -	68	43	53	43	41	40	111	84	93
25 lbs. Nitrogen, 1892, -	120	—	97	76	—	67	196	—	164
50 lbs. Nitrogen, 1890, -	82	58	57	58	53	44	140	111	101
50 lbs. Nitrogen, 1892, -	121	—	104	86	—	93	207	—	197
75 lbs. Nitrogen, 1890, -	100	68	79	78	87	67	178	153	146
75 lbs. Nitrogen, 1892, -	133	—	115	181	—	110	314	—	225

The preceding table gives the pounds of protein in the crop from one acre. This table takes into account the increased percentages of protein resulting from the addition of nitrogen in the fertilizer, and also the increased yield. In the protein from the total crop (both oats and straw) it will be noted that there is in each year, with each kind of nitrogenous fertilizer, an increase in the pounds of protein. It will also be noted here that in general the greatest difference in increase is between the addition of 50 pounds and the addition of 75 pounds of nitrogen per acre.

One hundred and sixty-two pounds of protein contain about 25 pounds of nitrogen. In other words, if a plant could assimilate and change 25 pounds of nitrogen into protein, 162 pounds would be formed. From this it follows that the application of 25 pounds of nitrogen in a fertilizer would, if all taken up and transformed by the growing plant, give 162 pounds of protein in the resulting crop. If we assume that the crop itself furnished no more nitrogen to the plants than was left behind in roots and stubble, and that no nitrogen was taken from the air, it will be seen that the application of more than 25 pounds of nitrogen per acre was, in each instance, made at a loss. That is, there was from 100 to 300 pounds less of protein found in the crop than might have been there if all of the nitrogen had been taken up and utilized. The protein of the crop was increased more by the application of nitrate of soda than by that of sulphate of ammonia or dried blood, and hence it follows that there was the greatest loss of nitrogen in the use of these fertilizers. This coincides with the results found in the special nitrogen experiment on grass.* In the case of the experiment with oats as in that with grasses, while the nitrogen was applied with pecuniary advantage, both as shown by the increased yield and the increased feeding value of the crop, the increase was obtained with a loss of nitrogen. The experiments were pecuniarily profitable, but viewed from the standpoint of the gain or loss of nitrogen, it is noticeable that there was a loss of a very considerable amount of the nitrogen supplied in the fertilizers.

SUMMARY.

The crops from two special nitrogen experiments with oats and one soil test experiment with oats have been analyzed.

The percentage of protein (nitrogen multiplied by 6.25) increased in both oats and straw with the application of nitrogen in the form of nitrate of soda or sulphate of ammonia, and this increase was somewhat in proportion to the amounts applied.

In the experiment of 1890 the use of different amounts of dried blood in the fertilizer did not materially affect the percentages of protein in either the oats or the straw. In 1892 there was an increase in the protein from the use of the largest amount (75 pounds nitrogen) of dried blood.

There was an increase in pounds of protein per acre in the plots supplied with nitrogenous fertilizers somewhat in proportion to the amounts applied. This increase was greatest in the plots to which nitrate of soda was applied. These results are in accord with observations made by the Station upon the relation of the protein in corn, and in grass, to the nitrogen applied in the fertilizers.

The increase in the amount of nitrogen in the crop did not equal the increase in the amount of nitrogen applied in the fertilizers, implying that the plants were not able to avail themselves of all the nitrogen supplied.

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*See this report, p. 44.

METEOROLOGICAL OBSERVATIONS.

BY C. S. PHELPS.

The meteorological records made at the Station during the past year have been similar to those of previous years. A list of the observations taken and the instruments in use will be found in the Report for 1890. In addition to the records made at the Station, the rainfall during the growing season has been recorded by those conducting field experiments in different parts of the State under the supervision of the Station.

The rainfall for the year (36.3 inches) as measured at the Station is much below the average. Six stations of the New England Meteorological Society having records covering a period of ten or more years previous to 1890, give an average annual precipitation of 49.1 inches. The records of this Station for the three years prior to 1892 give an average of 50.3 inches.

The precipitation was smallest during the months of February, April, September, and October. The rainfall for April (.70 inches) was the smallest for any month in the year. This prevented an early start in the grass crop and no doubt lessened the yield considerably. During the portion of the year when most crops were developing (May-August) the rainfall was about the average, so that farm crops as a rule were not greatly injured. Springs and wells, however, have rarely been known as low as in October.

The temperature for the first three months of the year was a little below the average, while the snowfall was light. April gave about the average temperature and the spring opened quite early. The last damaging frost occurred April 30. The weather during the months of May and June was favorable for nearly all farm crops. The summer was unusually warm and conditions were favorable for harvesting the hay crop.

The first killing frost occurred September 21. This gave a growing period of 144 days, since the last damaging frost in the spring. The average growing season for the past five years at Storrs is 142 days. The shortest period, 114 days in 1888, and the longest, 164 days in 1891.

September and October were characterized by unusually dry weather. Pastures were injured and all fall maturing crops suffered. The rainfall for November, however, was above the average, and wells and springs were generally replenished.

Through the kindness of the New England Meteorological Society we are able to publish rainfall records from their stations.

Table 16 gives the rainfall as recorded during the growing season in twenty-six localities in the State, and table 17 gives the summary of observations made at the Station at Storrs.

TABLE 16.

Rainfall during Six Months ending Oct. 31, 1892.

LOCALITY.	OBSERVER.	INCHES PER MONTH.						
		May.	June.	July.	August.	September.	October.	Total.
Falls Village,	M. H. Dean,	6.43	5.74	6.09	6.13	3.45	1.22	29.06
Oxford,	H. R. Stevens,	4.58	2.04	4.21	2.43	2.84	1.14	17.24
Norwalk,	G. C. Comstock,*	5.13	1.48	4.75	5.50	2.30	0.68	19.84
Waterbury,	N. J. Welton,*	5.55	2.27	4.37	5.30	2.62	0.92	21.03
New Hartford,	R. R. Smith,*	5.96	4.50	3.86	5.50	2.56	1.28	23.66
Canton,	G. J. Case,*	6.80	3.48	4.97	8.13	2.53	1.10	27.01
W. Simsbury,	S. T. Stockwell,*	6.17	3.17	4.47	5.38	2.01	0.90	22.10
Hartford,	Prof. S. Hart,*	5.65	1.78	3.29	5.51	1.90	1.28	19.51
Wallingford,	Mrs. B. F. Harrison,*	4.57	1.99	3.47	3.74	2.16	0.92	16.85
New Haven,	Weather Bureau,*	5.11	2.36	4.33	4.99	1.54	0.94	19.27
Middletown,	C. W. Hubbard,*	—	1.61	2.63	3.90	2.24	1.38	—
S. Manchester,	K. B. Loomis,	5.47	2.28	3.40	5.15	1.81	1.20	19.13
Vernon,	E. H. Lathrop,	5.10	3.06	7.02	4.94	2.30	1.48	23.90
Mansfield (Storrs),	Expt. Station,	5.60	2.77	3.25	5.20	1.40	1.09	19.31
N. Franklin,	C. H. Lathrop,	3.86	0.96	3.21	2.74	2.03	1.32	14.12
Lebanon,	J. H. Tucker,	5.93	1.59	2.82	3.54	2.27	1.81	17.96
Lebanon,	Edw. Hoxie,	5.71	1.46	3.56	3.11	1.90	1.77	17.51
Colchester,	S. P. Willard,*	5.05	—	3.33	3.91	1.34	1.28	—
New London,	Weather Bureau,*	4.07	2.46	2.57	3.45	2.04	0.98	15.57
Lake Konomore,	N. London Wat'r Wks.*	5.31	2.18	2.76	3.22	1.51	1.19	16.17
Voluntown,	Rev. E. Dewhurst,*	4.58	1.97	3.00	3.37	2.83	2.36	18.11
Brooklyn,	A. B. Webb,	4.24	2.59	2.47	3.97	2.00	0.00	15.27
Pomfret Landing,	E. T. White,	4.19	3.65	3.10	2.85	2.48	1.34	17.61
Putnam,	Jerome Warren,	4.97	3.90	2.60	3.72	—	—	—
N. Woodstock,	L. H. Healy,*	6.80	3.20	4.70	2.50	2.40	0.00	19.60
N. Grosv'nor Dale,	C. H. Truesdell,*	6.00	3.79	4.54	5.00	1.80	1.52	22.65
Average,		**5.31**	**2.65**	**3.80**	**4.35**	**2.17**	**1.16**	**19.67**

* New England Meteorological Society Observer.

TABLE 17.

Meteorological Summary for 1892.

OBSERVATIONS MADE AT THE STATION BY E. A. BAILEY AND S. H. BUELL.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.	Total.
Highest barometer, - - -	30.69	30.71	30.49	30.61	30.44	30.40	30.50	30.23	30.44	30.92	30.46	30.56	30.54	—
Lowest barometer, - - -	29.27	29.15	29.28	29.56	29.53	29.61	29.70	29.78	29.57	29.52	29.63	29.49	29.51	—
Mean barometer, - - -	30.01	30.14	29.93	30.03	29.99	29.95	30.04	30.01	30.16	29.98	30.05	30.02	30.03	—
Highest temperature, - -	58.2	43.8	55.0	75.9	80.5	90.8	92.0	88.5	78.0	74.5	63.5	46.5	70.6	—
Lowest temperature, - -	2.5	1.9	8.1	22.0	34.2	43.3	43.5	50.0	39.5	29.8	15.0	1.0	23.7	—
Mean temperature, - - -	25.5	26.9	29.9	44.9	53.6	67.0	69.2	67.4	59.1	48.5	37.6	25.5	46.3	—
Relative humidity, - - -	—	—	—	65.6	81.1	79.8	76.6	86.1	79.3	76.2	—	—	77.8	—
Total precipitation, - - -	4.91	1.60	3.00	.70	5.60	2.77	3.25	5.20	1.40	1.09	5.41	1.35	—	36.28
Number of days with precipitation of .01 inches or more,	9	7	7	5	15	12	9	10	4	5	11	6	—	100
Number of clear days, - -	7	9	12	10	4	6	13	9	19	12	11	12	—	124
Number of fair days, - -	12	6	10	14	13	17	12	11	5	9	7	10	—	126
Number of cloudy days, - -	12	14	9	6	14	7	6	11	6	10	12	9	—	116
Total movement of wind in miles,	8,500	7,737	11,721	8,312	6,618	5,554	5,008	4,361	4,000	5,534	5,565	6,832	—	—
Maximum velocity, - - -	60	50	60	42	32	36	36	30	40	36	48	50	—	—

EFFECT OF NITROGENOUS FERTILIZERS UPON THE PERCENTAGES OF PROTEIN IN GRASSES AND GRAINS.

BY CHAS. D. WOODS.

In the Annual Report of this Station for 1891* attention was called to the small proportions of protein in our feeding stuffs. Taken as a whole, they have a relative excess of the materials which serve the body of the animal for fuel and for making fat, while the protein compounds, which build muscle, tendon and other tissue, are relatively deficient. The same point is brought out in an article by Prof. W. O. Atwater in the Experiment Station Record, Vol. III., p. 676, from which the following is quoted:

"In the better cultivated parts of Europe much larger crops are generally grown than is usual with us. The statistics at hand imply that the grasses and forage crops at least are much richer in nitrogen.

Comparison of Proportions of Protein in American and European Grasses and Clover.

SPECIES.	AMERICAN.		EUROPEAN.	
	Specim's Analyzed	Protein in Water-free Substance.	Specim's Analysed	Protein in Water-free Substance.
		Per cent.		Per cent.
Timothy (Phleum pratense), - -	56	8.0	7	11.8
Orchard grass (Dactylis glomerata),	4	9.6	7	14.9
Blue grass (Poa pratensis), - -	18	11.8	6	11.6
Red clover (Trifolium pratense), -				
Pasture, - - - - -	—	—	18	25.5
In bud, - - - - - -	2	17.8	11	20.5
Early in blossom, - - -	—	—	19	17.9
Full blossom, - - -	5	15.7	46	16.1
Nearly ripe, - - - -	4	14.2	4	16.7

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* Page 168.

"In the preceding table are given the average percentages of protein in three common species of grasses and in red clover.

"The American figures are from the compilation of American analyses by Messrs. Jenkins and Winton.* The European are from *Dietrich und König's Zusammensetzung und Verdaulichkeit der Futtermittel* (second edition, 1891). In averages of analyses collated from such widely diverse sources it would be wrong to expect regularity, but taken together they show a most noteworthy advantage of the European products as compared with the American. The data at hand do not suffice for satisfactory comparisons of other grasses and legumes. Those for wheat show a preponderance of nitrogen in that from the better cultivated regions of continental Europe as compared with that from the United States. The comparative averages for the other grains, of which the number of analyses is smaller, are irregular.

"It looks very much as though we have by careless culture and insufficient manuring of our grasses and other forage crops, if not of our grains, for years been gradually breeding varieties poor in nitrogen, while in Europe the opposite course has been pursued. Certain it is that our grasses often contain smaller percentages of protein than are found in the best qualities of cornstalks, and even straw."

For four years the Station has conducted experiments on the effects of nitrogenous fertilizers in different amounts and combinations upon the growth of plants and their capacity to gather their nitrogen from natural sources. Descriptions of these experiments made in 1892 may be found in the article on the Effects of Nitrogenous Fertilizers Upon Grasses, page 36 of this Report, and in the accounts of coöperative field experiments with fertilizers beyond.

In connection with these experiments, a study of the proximate composition of the products grown was undertaken, so far as time would allow, in order to study among other things the effects of different fertilizers upon the percentage composition and upon the total yield of nutritive ingredients of the plant, *with especial reference to the effect of nitrogenous fertilizers upon the percentages and amounts of protein.*

The effects upon the percentages of protein in the plants as distinguished from the total amounts of protein in the crop are here discussed.

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* Experiment Station Bulletin, No. 11. Office of Experiment Stations, U. S. Department of Agriculture.

The results of analyses of the crops experimented upon seemed to point out that the percentages of protein were very decidedly affected by the quantities of nitrogen supplied in the fertilizer, and it is from the results of these experiments that we have been urging upon farmers greater attention to the culture and manuring of field crops than they have ordinarily received. The results of these analyses have been printed in previous Reports* which give the proximate analyses of the crops, and in many instances the yields per acre of the nutritive ingredients. These experiments, with scarcely an exception, have told the same story: *The addition of nitrogen in the fertilizer increased the percentages of protein in the crop.* In order to show concisely the results of our experiments upon this question, there is given in table 18, which follows, a summary of the results obtained by the use of nitrogenous fertilizers in varying quantities. Of course, the unevenness of the soils, some of which were deficient in nitrogen while others apparently had it in store in sufficient abundance for the needs of the plant, would make the deductions from any single experiment unreliable, but the average results of such a large number as are here reported upon, justify more or less definite conclusions.

In the table there is given in the first column the number of experiments upon which the averages are based. The remaining columns give the percentages of protein in the crop when grown without fertilizers, with mixed minerals (phosphoric acid and potash), and with mixed minerals to which nitrogenous fertilizers were added in quantities to supply 25, 50 and 75 pounds of nitrogen per acre.

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* Report of this Station, 1889, pages 127–178; 1890, pp. 44–56 and 93–111; 1891, pp. 29–40; this Report.

TABLE 18.

Effect of Nitrogenous Fertilizers upon the Percentages of Protein (Nitrogen × 6.25) in Grasses and Grains.

KIND OF CROP.	No. of Experiments.	Without Fertilizers.	Phosphoric Acid and Potash (Mixed Minerals).	Mixed Minerals and 25 lbs. Nitrogen per acre.	Mixed Minerals and 50 lbs. Nitrogen per acre.	Mixed Minerals and 75 lbs Nitrogen per acre.
		%	%	%	%	%
White flint corn,	3	13.1	12.5	12.5	13.3	14.4
Yellow flint corn,	3	11.6	9.9	10.2	10.5	11.8
Yellow flint corn,	3	12.1	11.4	12.7	12.2	13.2
Yellow flint corn,	3	11.6	10.9	12.7	11.8	12.0
Yellow flint corn,	3	12.5	9.7	9.7	9.7	10.1
Yellow flint corn,	3	11.4	10.9	10.3	10.9	11.0
Yellow flint corn,	1	11.0	10.9	11.0	—	11.9
Average,	**19**	**11.7**	**10.6**	**11.1**	**11.0**	**11.7**
White flint stover,	3	10.1	8.8	8.1	9.3	11.3
Yellow flint stover,	3	8.3	6.1	6.2	5.9	7.3
Yellow flint stover,	3	7.1	7.1	8.2	7.9	8.7
Yellow flint stover,	3	8.9	6.1	7.4	7.4	7.5
Yellow flint stover,	3	7.9	4.6	4.7	4.6	5.0
Yellow flint stover,	3	6.4	5.1	5.0	4.7	5.5
Yellow flint stover,	1	7.0	5.6	6.6	—	8.1
Average,	**19**	**7.6**	**5.8**	**6.4**	**6.1**	**7.0**
Oats,	3	13.7	14.3	14.7	15.2	15.5
Oats,	2	16.0	15.9	16.0	16.1	17.1
Average,	**5**	**14.9**	**15.1**	**15.4**	**15.7**	**16.3**
Oat straw,	3	8.7	6.0	5.4	5.8	6.3
Oat straw,	2	5.5	4.6	4.0	4.5	5.6
Average,	**5**	**7.1**	**5.3**	**4.7**	**5.2**	**6.0**
Mixed grasses,	2	7.3	8.2	8.0	8.2	9.2
Mixed grasses,	2	6.9	7.0	7.2	8.8	9.5
Mixed grasses,	1	7.7	10.9*	7.7	9.3	10.6
Average,	**5**	**7.3**	**7.6**	**7.6**	**8.8**	**9.8**
Orchard grass,	1	8.4	9.6	8.8	—	9.6
Orchard grass,	1	8.4	8.2	11.5	—	15.5
Average,	**2**	**8.4**	**8.9**	**10.2**	—	**12.6**
Timothy,	1	9.2	9.1	9.1	—	10.4
Timothy,	1	6.8	6.3	7.1	—	10.7
Average,	**2**	**8.0**	**7.7**	**8.1**	—	**10.6**
Tall red-top,	1	—	—	8.8	—	13.3
Tall red-top,	1	—	—	7.6	—	9.3
Average,	**2**	—	—	**8.2**	—	**11.3**
Smaller red-top,	1	—	—	8.4	—	11.9
Fowl meadow grass,	1	—	—	12.1	—	14.9
Rye grass,	1	—	—	10.9	—	12.6
Meadow fescue,	1	—	—	7.5	—	10.9
Kentucky blue grass,	1	—	—	12.9	—	15.4
Oat grass,	1	—	—	10.5	—	11.9
Brome grass,	1	—	—	10.6	—	11.0
Hungarian grass,	1	—	5.8	7.1	—	7.9
Average of grasses,	**19**	—	—	**8.3**	—	**10.9**

* Largely clover; omitted from average.

In the case of corn, as will be noted, the percentages of protein in the crop from the unfertilized plots were in every case nearly as large as that from the plot receiving the largest quantities of nitrogenous fertilizers, and in one instance the protein was 2.5 per cent. higher in the crop from the unfertilized than in that from the fertilized plots. The grain grown on the plots without fertilizers in nearly every case failed to mature properly, and the resulting corn consisted largely of "nubbins" and soft ears. The results of the analyses of "good" or merchantable corn and "poor" corn (soft ears and "nubbins") * indicate a great difference in the percentages of protein. The average of nine samples of "good" corn gave 11 per cent. protein, while the analyses of the "poor" corn from the same plots gave 12.5 per cent. protein. The percentages of protein in the "poor" corn exceeded that in the "good" by an average of 1.5 per cent., varying from a minimum of .75 to a maximum of 2.3 per cent. This is believed to be the explanation of the high percentages of protein in the corn grown without fertilizers. It is a well established fact that immature plants contain relatively a larger amount of protein than do mature, and in the majority of instances, the plants grown without fertilizers made poor development. Apparently the undeveloped plant has relatively little starch and other carbohydrates. On this account the effects of the nitrogen are best observed in comparing the produce from the mixed minerals plots (superphosphate and muriate of potash) with that from the plots which received nitrogen in addition to the mixed minerals.

The differences between the crops grown with mixed minerals alone and mixed minerals plus 25 pounds of nitrogen per acre, were in some cases slight. It may be that in these cases the soil contained enough available nitrogen for the needs of the plant, and that the addition of the small quantity did not suffice to produce any marked effect upon the composition of the crop, since, in these cases, it added so greatly to the total yield † that the effect would not be visible in percentage composition. There may be still another reason for the apparent slight increase in the percentage of protein with the increase in the nitrogen applied, namely, that the samples analyzed did not accurately represent

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* Report of this Station 1890, pages 26-28.

† By reference to the places cited in a foot note on the previous page, where the results of this work have been printed in detail, it will be seen that the yield of protein per acre was quite markedly increased by the addition of 25 pounds of nitrogen.

the whole crop. The results of the analyses of corn, grain and stover, are less satisfactory, and particular instances are less reliable than in the case of the other crops. After the analyses of quite a number of corn experiments had been made, with results somewhat difficult to interpret, a study was made on the sources of error in obtaining field samples,[*] with the result that duplicate samples from the same plot, even when taken with great care, showed very considerable variations in composition. In the case of such a plant as corn, where naturally only a comparatively small number of plants would enter into the sample, the variations due to errors in obtaining samples were found to be considerably greater than in the case of plants like grass or oats, where a much larger number of plants would be taken. It would seem, however, that the number of trials averaged must be sufficient to make the inferences reasonably reliable for the conditions under which the experiments were made.

SUMMARY.

The results of 73 experiments upon the effect of nitrogenous fertilizers upon the protein of the crop have been given in detail in the present and earlier Reports of the Station,[†] *and are concisely summed up in the following table:*

Results of Analyses showing Relation between Nitrogen applied in Fertilizers and Protein (Nitrogen × 6.25) found in Resulting Crops.

KIND OF CROP.	No. of Experiments.	Phosphoric Acid and Potash (Mixed Minerals).	Mixed Minerals and 25 lbs. Nitrogen per acre.	Mixed Minerals and 50 lbs. Nitrogen per acre.	Mixed Minerals and 75 lbs. Nitrogen per acre.
		%	%	%	%
Corn (grain),	22	10.9	11.3	11.4	12.1
Oats (grain),	5	15.1	15.4	15.7	16.3
Corn stover,	22	6.2	6.6	6.6	7.6
Oat straw,	5	5.3	4.7	5.2	6.0
Mixed grasses,	5	7.6[‡]	7.6	8.8	9.8
Orchard grass,	2	8.9	10.2	—	12.6
Timothy,	2	7.7	8.1	—	10.6
Red-top,	3	—	8.3	—	11.7
Seven other pure grasses,	7	—	10.2	—	12.1

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[*] Report of the Station, 1890, pages 120–135.

[†] See foot note, page 62.

[‡] Included more clover than other plots.

The results as shown in the table need no explanation, as the figures tell the story so plainly. In each case, except that of oat straw, the percentages of protein were greater when nitrogen was applied in the fertilizers than when it was not. In general, the percentages of protein increased with the amount of nitrogen applied, though, in most cases, the application of the largest amount of nitrogen seemed to have the most marked effect upon the protein of the crop.

PRACTICAL CONCLUSIONS.

The Station has for years been urging upon the attention of farmers that the value of nitrogenous feeding stuffs is not sufficiently appreciated. The progress of exact experiment is bringing this fact out more and more clearly. Thus the experiments on the effects of fodder upon the production of milk, lately made in some of our Stations, emphasize most forcibly the need of rations much richer in protein than most farmers feed. Similar and still more striking results have been found in an extended series of experiments on feeding cows for milk and steers for fattening, conducted on a number of farms in Prussia.

Our crops contain a large excess of the materials which serve as fuel, while the protein compounds which make muscle, bone, and milk are relatively wanting. The farmer is primarily responsible for this state of affairs, and must be the one to take the first steps to amend it. The protein needed for the use of the stock kept on the farm may be obtained in one of three ways. It may be purchased in the form of concentrated feeds, such as wheat bran, oil meals, etc.; it may be obtained by growing the legumes which are able to obtain nitrogen directly from the air and convert it into protein; or it may be obtained by breeding and importing varieties of grains and grasses richer in nitrogen than those now cultivated. While it is probable that the feeder must, for the present, continue to buy some of the protein which his animals need, still by care in selection of crops, and by growing plants richer in nitrogen, much more protein may be produced on the farm itself. This protein is needed for fodder in order to make leaner meat, and more of it, and more milk at less cost. The nitrogen not transformed into meat or milk makes rich manure for grasses, grains and other crops, and the rich manure helps to bring larger crops, and crops richer in protein.

RESULTS OF EXPERIMENTS WITH FERTILIZERS ON DIFFERENT CLASSES OF SOILS.

BY C. S. PHELPS.

The object of this paper is to summarize the results of about 90 soil test experiments with fertilizers, conducted in this and other New England States during the past 15 years The results of the experiments have been studied with reference to the classes of soils, for the purpose of ascertaining the relations, if any, between the kinds of soils and their deficiencies. The results have been summarized and tabulated in two groups: (1) Soils ranging from sandy to loam, and (2) soils ranging from heavy loams to heavy clays. Many of the experiments could not be included in either of these groups owing to the absence of sufficient data, or the variable character of the soil. In such cases the experiments have been omitted from the tabulations. At the close of this article will be found a series of tables giving the results in detail for the different classes of soils.

EXPERIMENTS MADE DURING THE YEARS 1878–81.

In the year 1877 the Director of this Station, then Director of the Connecticut Agricultural Experiment Station, inaugurated a series of field tests with fertilizers by farmers and scientific men in different parts of the country. The experiments were largely on corn, although potatoes, turnips, oats and other crops were included. They were continued under his direction during a series of years, and in a number of instances are still being carried on. The purpose of the experiments as then stated is given in the following extract from the report of that Station for 1876:

"One of the fundamental results of the vast amount of work done in field experiments with fertilizers is the clear demonstration that soils vary greatly in their capabilities of supplying food to crops, that different ingredients are deficient in different soils, and that the teachings of any given experiment are in the main applicable only to the particular kind of soil on which it is made.

"For farmers who have not their own experience, or that of others in like circumstances, to guide them, the most sensible method for determining what are the deficiencies of their soils, and how they will be the most economically supplied to given crops, is to try experiments on a small scale; to put the question to the soil with different fertilizing materials and obtain its reply in the crops produced."

These experiments were conducted over a wide range of country, although the greater part were in the New England States, New York, and New Jersey. They were carried out in accordance with printed directions sent out by Prof. Atwater. Many were evidently conducted with care and thoroughness, while others were of little value. Those showing discrepancies in the work, or abnormal results due to soil variation, weather, or other causes, have been discarded, and only those used that appeared to furnish results of value. For the purpose of this article, only the experiments made in New England have been included.

Reports on these experiments and tabulations giving results in detail will be found in the reports of the Connecticut Board of Agriculture for the years 1878, 1879, 1880, and 1881, and also in pamphlet form as reported for the U. S. Department of Agriculture in 1883.

The following is taken from the latter report, and indicates some of the difficulties met with and an estimate of the value of the work, by Prof. Atwater, after five years' experience with this class of experiments:

"Many of the reports have no decided story to tell, and some none at all, except failure everywhere. Some were on land so rich that the action of the fertilizers was obscured by the stores of plant-food in the soil; others on soil seemingly in such physical condition that no artificial supply of plant-food could make it fertile. The most serious difficulty of all has been found in the unevenness of the soil. The plots on one side were dryer than on the other; or one plot was on old sod ground and another had been lately cultivated, and showed the effects of previous manuring; while some were irregular for reasons upon which the reports throw no light. On the whole, the general character of the work, as evidenced by the reports, is a most forcible illustration of the truth that among our farmers there is an amount of intelligence and ability which is not appreciated either by themselves or by the community at large, but which is capable of making, indeed is making, a very rapid advance in the intellectual character of our agriculture."

EXPERIMENTS MADE DURING THE YEARS 1888–91.

Since the organization of the Storrs School Station, in 1888, similar soil test experiments with fertilizers have been carried out. The general plan* is the same as for those conducted in this and other States during the years 1878–81. The work, however, has been more closely under the direction of the Station; either the Agriculturist or his assistant having supervision of the more important operations, such as the laying out of plots, application of fertilizers, harvesting and weighing the crop, etc.

The following from a previous report gives the object and purpose of the experiments:

1. To work directly upon farm lands in different parts of the State, and to aid the owners in learning the deficiencies of their soils and the requirements of their crops.

2. To help farmers in becoming familiar with the forms and action of fertilizing materials containing phosphoric acid, potash, and nitrogen, and to better understand their profitable use.

3. To encourage a spirit of investigation, and thus to gradually develop a number of farm experimenters, whose work will be useful not only to themselves, but in a large degree to their communities and to the agriculture of the State.

These experiments are, perhaps, of greater value to the farmer who conducts them than to any one else; not only does he gain a knowledge of particular soils, but at the same time he is led to appreciate the great need and importance of scientific work. Through discussions in Granges and Farmers' Clubs he also succeeds in interesting many others. The value of the tests and their application become more general where they are continued over a period of years.

THE PLAN OF SOIL TEST EXPERIMENTS.

The plan of experiments for soil tests consisted in applying, on parallel plots of land, fertilizers containing nitrogen, phosphoric acid, and potash, singly, two by two, and all three together. The fertilizing materials were in all cases supplied by the Station, in standard commercial forms, and consisted of nitrate of soda, dissolved bone-black, muriate of potash, and land plaster.

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* See Report of this Station, 1890, pp. 87–93.

AVERAGE RESULTS WITH SOIL TESTS ON HEAVY AND LIGHT SOILS.

In table 19, which follows, will be found the average yields of shelled corn for 31 experiments conducted in various parts of New England during the years 1878–81, and 20 experiments made in this State under the charge of the Station in 1888–91. In each case the experiments have been divided into two groups—first, soils ranging from sandy to loam (light soils), and second, from loam to heavy clay (heavy soils).

TABLE 19.

Average Yields of Shelled Corn per Acre on Heavy and Light Soils.

No. of Plot.	Kind of Fertilizers.	1878–1881.				1888–1891.			
		Fertilizers.		Av'g 20 Exp'ts, Light soils.	Av'g 11 Exp'ts, Heavy soils.	Fertilizers.		Av'g 12 Exp'ts, Light soils.	Av'g 8 Exp'ts, Heavy soils.
		Weight.	Cost.			Weight.	Cost.		
		Lbs.	$	Bu.	Bu.	Lbs.	$	Bu.	Bu.
O	Nothing, - -	—	—	25.5	20.8	—	—	16.9	15.3
A	Nitrate of Soda, -	200	7.50	33.3	24.7	160	3.96	22.8	19.5
B	Dis. Bone-black, -	300	5.25	35.1	35.2	320	4.40	19.5	27.2
C	Muriate of Potash,	200	4.50	34.3	25.9	160	3.48	25.9	20.4
D	Nitrate of Soda, - Dis. Bone-black, -	150 300	10.88	41.4	38.8	160 320	8.48	26.8	30.4
E	Nitrate of Soda, - Muriate of Potash,	150 200	10.13	35.5	25.9	160 160	7.52	34.7	19.3
F	Dis. Bone-black, - Muriate of Potash,	300 200	9.75	40.1	38.8	320 160	8.00	28.0	32.9
G	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash,	150 300 200	15.38	50.3	41.0	160 320 160	12.00	38.4	33.2
H	Plaster, - -	200	.80	27.5	26.4	400	1.70	21.2	18.5
O	Nothing, - -	—	—	31.9	27.6	—	—	18.2	22.3

In table 20, on the next page, are given the average results from the use of the different fertilizing ingredients (nitrogen, phosphoric acid, and potash).

These figures were obtained by averaging the yields on all of the fertilized plots (four) receiving nitrogen, and on all (four) having no nitrogen. The difference between these two averages was considered to be the gain or loss due to the use of nitrogen. The gain or loss from the use of phosphoric acid and potash was obtained in a similar way. By comparing the gain or loss from the use of nitrogen, with the gain or loss from the use of phosphoric acid and potash, it becomes evident which ingredient had the ruling effect in each experiment.

TABLE 20.

Average Yields of Shelled Corn per Acre from the Use of the Different Fertilizing Ingredients.

		Number Experim'ts.	Nitrogen.			Phosphoric Acid.			Potash		
			Plots With.	Plots Without.	Gain or Loss (−).	Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.
			Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Light Soils	1878-81,	17	38.7	33.8	4.9	39.5	32.9	6.6	38.6	34.0	4.6
	1888-91,	12	30.8	24.5	6.3	27.9	27.8	0.1	31.8	23.0	8.8
	1878-91,	29	35.4	29.9	5.5	34.7	30.7	4.0	35.8	29.5	6.3
Heavy Soils	1878-81,	10	32.5	32.0	0.5	38.2	24.7	13.5	32.6	31.6	1.0
	1888-91,	18	25.6	26.8	−1.2	30.9	19.8	11.1	26.5	26.1	0.4
	1878-91,	18	29.4	29.2	0.2	35.0	22.5	12.5	29.9	29.2	0.7

In the earlier experiments (1878–81) on sandy to loam soils, phosphoric acid had the leading effect in eight experiments, potash in five, nitrogen in three, and nitrogen and potash were alike in one. In the later experiments (1888–91) the lighter soils were more generally benefited by potash fertilizers. Of the twelve experiments on this class of soils all but two showed a marked increase of crop where potash was used; in only one case was there any considerable increase from the use of phosphoric acid, while with nitrogen all but one gave more or less increase.

In the earlier experiments, on heavy loam to heavy clay soils, phosphoric acid had the leading effect in eight experiments, potash in one, and potash and nitrogen were alike in one; while for eight experiments made during 1888-91 on this class of soils, every one showed considerable increase of crop from the use of phosphoric acid, only two gave any increase with potash, while with nitrogen there was no increase of account in any of the experiments.

The results of the earlier experiments on light soils seem to differ somewhat from those made in Connecticut during the past four years. In the earlier experiments, in the majority of cases, phosphoric acid gave the most marked increase of crop, while in several potash produced the greater yield. These experiments indicate that such soils, as a whole, are more apt to be lacking in two or three of the essential ingredients (nitrogen, phosphoric acid, and potash) than are the heavier soils. In the case of experiments made on Connecticut soils of this class since the year 1888 the results are somewhat different. The crops grown on light soils were in nearly all cases greatly increased by the use of potash, or nitrogen, or both, while in only one case was there any considerable increase from the use of phosphoric acid. *The experiments thus far made indicate that for corn on the lighter soils of the State, fertilizers containing a large proportion of potash are needed to give the best results.*

On the other hand, in the case of the heavy soils, nearly all of the experiments recorded indicate a lack of phosphoric acid. With only one or two exceptions, phosphoric acid has greatly increased the yield, especially of grain, while a much smaller increase has resulted from the use of either potash or nitrogen. *The results thus far reached point to the conclusion that for corn, fertilizers with relatively large proportions of phosphoric acid produce the best results on heavy, clayey soils.*

It is of interest also to notice the effect of nitrogen on the two classes of soils. In the majority of cases, on the light soils, corn was considerably benefited by nitrogen. The average increase on the fertilized plots having nitrogen over those without, in 29 experiments on light soils, was 5.5 bushels. In the 18 experiments made on the heavy soils, nitrogen gave an increase above two bushels in only three experiments, and the average yield per acre was only two-tenths of a bushel more with nitrogen than on the plots where no nitrogen was applied. The results seem to indicate that soluble nitrogen compounds, like nitrate of soda, cannot be economically used for corn on heavy soils in this region.

EXPERIMENTS ON POTATOES.

A series of experiments similar to those made on corn during the years 1878–81, were also made on potatoes The kind of fertilizers used and the general plan were the same in the two cases.

The results of fourteen of these experiments have been tabulated and divided into classes according to the character of the soils, the same as for the corn experiments. The number of experiments, however, is too small for making general deductions, although the results appear to be worthy of consideration, as they tend to corroborate those obtained on corn.

TABLE 21.

Average Yields in Potato Experiments (1878–81).

No. of Plot.	FERTILIZERS PER ACRE.			Light Soil Exp't.	Heavy Soil Exp't.
	KIND.	Weight.	Cost.	Bu. per Acre.	Bu. per Acre.
		Lbs.	$		
O.	Nothing, - - - - - -	—	—	65.7	97.9
A.	Nitrate of Soda, - - - - - -	200	7.50	79.0	98.5
B.	Dissolved Bone-black, - - - - -	300	5.25	91.1	132.1
C.	Muriate of Potash, - - - -	200	4.50	96.5	118.7
D.	Nitrate of Soda, - - - - - - Dissolved Bone-black, - - - - -	150 300	10.88	91.5	147.0
E.	Nitrate of Soda, - - - - - - Muriate of Potash, - - - -	150 200	10.13	80.1	105.7
F.	Dissolved Bone-black, - - - - - Muriate of Potash, - - - -	300 200	9.75	103.2	170.6
G.	Nitrate of Soda, - - - - - - Dissolved Bone-black, - - - - - Muriate of Potash, - - - -	150 300 200	15.38	138.9	193.3
H.	Plaster, - - - - - -	200	.80	62.4	117.3
OO.	Nothing, - - - - - -	—	—	—	94.0

TABLE 22.

Average Yields of Potatoes per Acre from the Use of Different Fertilizing Ingredients.

KIND OF SOIL.	Nitrogen.			Phosphoric Acid.			Potash.		
	Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.	Plots With.	Plots	Gain With.
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Light Soils, -	98.9	92.9	6.0	106.2	85.2	21.0	106.2	85.0	21.1
Heavy Soils, -	128.4	121.7	6.7	150.2	98.9	51.3	137.9	112.2	25.7

In table 21 above will be found the average yields per acre on the various plots, and the average yields, together with the gain or loss, from the use of the different fertilizing ingredients.

In the case of the lighter soils only five experiments are reported. In most cases all three ingredients (nitrogen, phosphoric acid, and potash) gave considerable increase in the yield, while the average gain from the use of phosphoric acid was the same as with potash.

With the heaviest soils, in nearly all cases, there was an increase in the yield from each of the essential ingredients, but the increase from the use of phosphoric acid was double that from the use of potash. *These experiments indicate that for potatoes as well as for corn, heavy soils of a clayey character usually need to be supplied with fertilizers containing large amounts of available phosphoric acid, while potash may be more sparingly used.*

EXPERIMENTS BY THE HATCH STATION, MASSACHUSETTS.

A series of soil tests on corn have been carried on for three years in Massachusetts, under the direction of Prof. William Brooks, of Amherst. Nearly all of these were made on light soils, varying from sandy loam to loam. Wherever serious variations appeared, or abnormal yields have occurred, or when the character of the soil could not be determined from the data given, the experiments have not been used for the calculations herewith. Fifteen experiments are here tabulated, all of which were on the lighter soils. The average yields per plot and the average results with nitrogen, phosphoric acid, and potash, are given in the table which follows, for the fifteen experiments on light soils.

TABLE 23.

Experiments on Corn in Massachusetts. Light Soils.

No. of Plot.	FERTILIZERS PER ACRE. Kind.	Weight.	15 Experim'nts Shelled Corn, per Acre.
		Lbs.	Bu.
O.	Nothing,	—	24.0
A.	Nitrate of Soda,	160	31.1
B.	Dissolved Bone-black,	320	29.2
O.	Nothing,	—	25.6
C.	Muriate of Potash,	160	34.8
D.	Nitrate of Soda, Dissolved Bone-black,	160 320	34.0
E.	Nitrate of Soda, Muriate of Potash,	160 160	37.2
O.	Nothing,	—	27.2
F.	Dissolved Bone-black, Muriate of Potash,	320 160	38.8
G.	Nitrate of Soda, Dissolved Bone-black, Muriate of Potash,	160 320 160	45.2
H.	Plaster,	160	27.0
O.	Nothing,	—	26.3

BUSHELS PER ACRE WITH DIFFERENT FERTILIZERS.	Plots With.	Plots Without.	Gain With.
Nitrogen.	36.9	32.5	4.4
Phosphoric Acid.	36.8	32.5	4.3
Potash.	39.0	30.3	8.7

It is of interest to note how generally these soils responded in the crop to the use of potash fertilizers. The results are in close accord with those obtained on soils of the same character in this State, and naturally lead to the conclusion that soils of this character are deficient in available potash and fail to produce good crops unless potash fertilizers are liberally supplied. It seems doubtful, however, if the same results would have followed on heavy, clayey soils, in Massachusetts especially, where such soils are in the granitic regions of the State. Only three of the experiments reported were on clayey soils. Of these two were in the Connecticut valley, in what is known as the old lake bottom of the Hadley meadows. All soils of this region, as far as tested, seem to show a lack of potash, and it is reasonable to conclude that the potash compounds, being more or less soluble, were not deposited from the water of this old lake. The other experiment is in the Housatonic valley, and is described as "alluvial, fine compact loam, with a tendency to clay." This soil is in a limestone region, which fact would probably account for the apparent lack of potash. Soils of this same geological formation, further south in Connecticut, have shown a similar lack of potash.

The soils of the granitic regions of both Connecticut and Massachusetts are quite similar in their origin and composition. As clay is formed from the decomposition of feldspar, from which it gets considerable potash, it is natural to conclude that such soils will not be as noticeably benefited by potash fertilizers as the lighter and more sandy soils. This conclusion is strengthened by experiments made in nearly all the New England States. In almost all experiments reported with corn on clayey soils of granitic origin, potash has caused but little increase of crop, while phosphoric acid has generally given a marked increase.

EXPERIMENTS AT THE RHODE ISLAND STATION.

The experiments reported from Rhode Island were made under the direction of the chemist of the Rhode Island Station, Dr. Wheeler. They are the soil test portions of special nitrogen experiments on corn. The experiments were undertaken for the purpose of studying the deficiencies of soils, and the relative effects of smaller and larger quantities of nitrogen. The special nitrogen portions of the experiments have not been used in this article.

TABLE 24.

Experiments on Corn in Rhode Island. Light Soils.

Number of Plot.	FERTILIZERS PER ACRE. Kind.	Weight.	Cost.	15 Experiments Shelled Corn, per Acre.
		Lbs.	$	Bu.
0	Nothing, - - - -	—	—	20.0
1	Nitrate of Soda, - -	150	3.60	27.3
2	Dissolved Bone-black, -	350	4.38	31.3
3	Muriate of Potash, - -	130	3.06	30.5
4	Nitrate of Soda, - 150 Dis. Bone-black, - 350	500	7.98	39.1
5	Nitrate of Soda, - 150 Muriate of Potash, 130	280	6.66	32.8
6	Dis. Bone-black, - 350 Muriate of Potash, 130	480	7.44	38.3
7	Nitrate of Soda, - 150 Dis. Bone-black, - 350 Muriate of Potash, 130	630	11.04	42.1
00	Nothing, - - -	—	—	24.5

BUSHELS PER ACRE WITH DIFFERENT FERTILIZERS.	Plots With.	Plots Without.	Gain With.
Nitrogen.	35.7	33.4	2.3
Phosphoric Acid.	37.1	30.5	6.6
Potash.	35.9	32.6	3.3

Nearly all the experiments were made on the lighter class of soils, varying from sandy to loam. In a few cases the data indicated that the soils were of a clayey character, and these were omitted from the tabulations.

From the results on this class of soils it will be seen that no one ingredient was beneficial to the exclusion of others. Phosphoric acid is seen to have the leading effect on the crop, when the results of the three ingredients are compared. This does not corroborate the results on similar soils in Connecticut and Massachusetts, and goes to show that such soils are not likely to be uniform in their deficiencies.

Many of the experiments were conducted for two successive years on the same soil. In such cases the benefit derived from any single ingredient would be more striking the second season, and hence the average increase from phosphoric acid would probably not have been as great had the experiment been made on a larger number of soils. It would be of interest also to ascertain the results on soils of a clayey nature to compare with those on the lighter soils. From the general similarity of the soils in this State and Rhode Island it would seem probable that the heavier soils would indicate similar needs. In fact, in one or two experiments reported, made on clayey soils, phosphoric acid did produce the most marked effect, although the number of such experiments was not sufficient to warrant their tabulation.

THE VALUE OF THE EXPERIMENTS AND PRACTICAL DEDUCTIONS.

THE VALUE OF SOIL TESTS.

Coöperative field experiments with fertilizers by farmers have become a part of the work of quite a number of the Experiment Stations of the country. They have an especially important place in these States where commercial fertilizers are extensively used. The object aimed at is to study the soils of different regions, learn their deficiencies, and find how to apply fertilizers so as to meet the needs of particular soils and crops in an economical manner.

The wide variations in soils indicate that the results of any one experiment are applicable only to the particular soils experimented upon, or to soils of a similar character. Where this class of experimenting is wholly on the Station farm, the work has only a local value, and in order to make the experiments of highest value to the farmers of the State they must be carried out in a considerable number of places.

If the important operations, such as the selection of the field, the laying out of the plots, the planting, the application of the fertilizers, and the weighing and the harvesting of the crop, are under the supervision of an officer of the Station, there is no reason why the work cannot be carried out with the same degree of accuracy as at the Station.

UNIFORM SOILS AND THOSE DEFICIENT IN PLANT FOOD NEEDED.

For soil test experiments with fertilizers, poor and uniform soils should be selected. The object of such experiments is to learn what the soil can do of itself without the aid of added stores of plant food, and not to obtain, primarily, large crops.

If the soil lacks uniformity, or has an abundance of available plant-food, it will be impossible to judge how much of the growth is due to the plant-food in the fertilizer applied, and how much to that previously stored in the soil. Just here is the chief difficulty with field experiments, and one that tends to make the results unreliable, unless the experiments are carried through a series of years. It is almost impossible to find a field of one or two acres that is uniform throughout. Soils vary greatly as to the amounts of available plant-food they contain; as to the relative amount of sand, clay, or humus present; as to fineness of texture, slope, powers of absorbing and retaining heat and moisture; and as to their powers of holding, in an available form, the fertilizing ingredients supplied. The subsoil also exerts considerable influence, especially in regulating the supply of moisture from the ground water.

DIFFERENCES IN SOILS.

Connecticut soils, being of the drift formation, are very complex in their make-up. Little can be learned with regard to their composition by a study of the rocks.

One soil may be made up largely of silica or quartz, while only a few rods away another may have been formed from feldspathic or potash containing rocks. Under these circumstances their natural fertility will vary greatly.

Chemical analysis of soils has not been found to be a satisfactory means of determining their fertility. While the analysis may show the composition of the particular sample analyzed, it fails to indicate the amount of plant-food that may be available to the crop.

In the so-called "soil tests" the plant acts as its own chemist. By applying the elements most commonly lacking, namely, nitrogen, phosphoric acid, and potash, singly and in combinations, to different plots of land, we enable the plants to draw from the soil the ingredients not supplied. If any of these constituents are already present in the soil in considerable quantities, the results in the crop will soon indicate it, and if any are lacking poor crops will result, until the needed fertilizing materials are supplied in an available form.

THE RELATIVE IMPORTANCE OF PHOSPHORIC ACID AND POTASH.

Many soils have supplies of phosphoric acid and potash that can be drawn upon, year by year, without materially lessening their productiveness. The soils of the Housatonic Valley, which have been experimented upon, seem to contain large quantities of phosphates and to be lacking in potash. In many parts of the State potash feldspar is abundant in the soils, and hence they are generally quite well supplied with potash, although they show a decided lack of phosphoric acid. The beneficial effects of phosphoric acid are especially noticeable in the case of experiments made on the heavy soils in the towns of Lebanon, Putnam, Woodstock, and Pomfret, and this would probably prove true on soils of a similar character in other parts of the State. The work thus far done points strongly to the conclusion that heavy, clayey soils in Connecticut need to be supplied with large amounts of phosphoric acid in the fertilizers used, while light sandy to loam soils are more generally, although not uniformly, helped by potash fertilizers.

IMPORTANCE OF NITROGEN.

Nitrogen holds in plant life and in the economy of the farm a very different position from phosphoric acid, potash, or lime. In the first place, it is the most costly ingredient of fertilizers; and, secondly, it is the most changeable and uncertain. It is supplied to our soils by commercial fertilizers, either as organic compounds, as in dried blood, fish, etc., as salts of ammonia, as sulphate of ammonia, or in the form of nitrates, but it is only in the form of nitrates, as in nitrate of soda, that plants can utilize it to any great extent. The other forms must be partly or entirely changed into nitrates before they become available to the plant. These changes take place after the fertilizer is added to the soil.

Nitrogen is readily lost in the drainage unless there is a crop on the soil that is in condition to utilize it. If the soil is left without a crop for any considerable length of time, much of the nitrogen will pass into the drainage in the form of nitrates. For the same reason, it should not be applied long before the crop is ready to use it. Nitrogen varies in its effects on corn in accordance with the kind of soil. The teaching of the experiments thus far made in Connecticut is that when nitrogen is used on the lighter class of soils the crop is most benefited. Such fertilizers as nitrate of soda and sulphate of ammonia can generally be used with profit on light loam soils. For some unexplained reason, however, soluble nitrogen compounds, such as nitrate of soda, rarely prove of much value for corn on heavy, clayey soils. Nitrogen is needed in order to get large crops of corn on these soils, and good results are generally obtained from the use of organic nitrogen in the form of slowly decaying vegetable matter.

On such soils the best financial results with corn are generally obtained by the use of yard manures as a source of nitrogen, and by commercial fertilizers to furnish the mineral ingredients that are lacking in the soil.

CONCLUSIONS.

Soils cannot be cultivated to the greatest profit without a knowledge of their deficiencies, as regards plant-food. Soil tests with fertilizers seem to be the best practical means for ascertaining these deficiencies in particular soils.

Heavy, clayey soils need to be supplied with large amounts of phosphoric acid in the fertilizers used, while light, sandy to loam soils are more generally, though not uniformly, helped by potash fertilizers.

The teachings of the experiments thus far made in Connecticut indicate that nitrogen is most beneficial on the light class of soils. Soluble fertilizers, as nitrate of soda and sulphate of ammonia, can generally be used with profit on light loam soils, but do not prove of much value for corn on heavy soils. For heavy soils nitrogen should be supplied in some organic form, as stable manure, dried blood, etc.

The wide differences found in soils afford a strong argument in favor of home mixed fertilizers. The special needs of different soils cannot be considered by the manufacturer who prepares his fertilizers for general use. The farmer may, however, prepare such mixtures as will meet both the deficiencies of his soil and the requirements of his crops.

NAMES AND ADDRESSES OF EXPERIMENTERS.

1. W. I. Bartholomew, Putnam, Conn.
2. Prof. J. R. Farrington, Orono, Me.
3. Edw. F. Smith, Tunbridge, Vt.
4. W. I. Bartholomew, Putnam, Conn.
5. J. W. Pierce, West Millbury, Mass.
6. Zeno Benson, Bridgewater, Mass.
7. E. N. Bissell, E. Shoreham, Vt.
8. W. H. Pillbrook, North Hampton, N. H.
9. Prof. W. H. Jordan, Orono, Me.
10. W. I. Bartholomew, Putnam, Conn.
11. H. F. Cox, Brooklyn, Conn.
12. W. I. Bartholomew, Putnam, Conn.
13. K. B. Loomis, S. Manchester, Conn.
14. J. H. Tucker, Lebanon, Conn.
15. L. H. Healey, N. Woodstock, Conn.
16. Clifton Peck, Franklin, Conn.
17. Storrs School Station, Mansfield, Conn.
18. Jerome Warren, Putnam, Conn.
19. James K. Toby, Calais, Vt.
20. Hiram A. Cutting, Lunenburg, Vt.
21. Prof. J. Farrington, Orono, Me.
22. W. I. Bartholomew, Putnam, Conn.
23. Edward M. Snow, Mansfield, Vt.
24. Hiram A. Cutting, Lunenburg, Vt.
25. A. N. Foster, Cabot, Vt.
26. W. I. Bartholomew, Putnam, Conn.
27. M. H. Dean, Falls Village, Conn.
28. Z. E. Jameson, Irasburgh, Vt.
29. Seth H. Rising, West Rupert, Vt.
30. Chas. B. Gale, Plainfield, Vt.
31. R. Bradley, Brattleboro, Vt.
32. W. C. Atwood, Watertown, Conn.
33. J. M. Manning, Taunton, Mass.
34. Zeno Benson, Bridgewater, Mass.
35. W. S. Simmons, Plymouth, Mass.
36. C. Miller & Sons, Pomfret, Vt.
37. J. M. Manning, Taunton, Mass.
38. J. A. Chedel, So. Pomfret, Vt.
39. Chester Sage, Middletown, Conn.
40. J. D. Winslow, Pittsford, Vt.
41. J. M. Manning, Taunton, Mass.
42. Henry Gaylord, Cheshire, Conn.
43. Chas. Fairchild, Middletown, Conn.
44. J. H. Pann, Middleboro, Mass.
45. A. C. Blake, New Britain, Conn.
46. Frank Day, Danielsonville, Conn.
47. M. H. Dean, Falls Village, Conn.
48. M. H. Dean, Lime Rock, Conn.
49. R. S. Hinman, Oxford, Conn.
50. A. C. Blake, New Britain, Conn.
51. Frank Day, Danielsonville, Conn.
52. M. H. Dean, Falls Village, Conn.
53. R. S. Hinman, Oxford, Conn.
54. C. E. May, E. Woodstock, Conn.
55. H. W. Sadd & Son, Wapping, Conn.
56. F. L. Ensworth, Canterbury, Conn.
57. S. P. Richmond, Freetown, Mass.
58. Wm. S. Phillips, Jr., Marblehead, Mass.
59. Dole Brothers, Shelburne, Mass.
60. Pliny Moore, Worcester, Mass.
61. Experiment Station, Amherst, Mass.
62. Wm. S. Phillips, Marblehead, Mass.
63. A. D. Copeland, Bridgewater, Mass.
64. S. P. Richmond, Freetown, Mass.
65. J. Bryden, Yarmouth, Mass.
66. Pliny Moore, Worcester, Mass.
67. Chas. F. Fowler, Westfield, Mass.
68. Dole Brothers, Shelburne, Mass.
69. Experiment Station, Amherst, Mass.
70. G. L. Cooley, Sunderland, Mass.
71. F. E. Clark, Wilbraham, Mass.
72. Experiment Station, Kingston, R. I.
73. H. E. Lewis, Hope Valley, R. I.
74. G. B. Vaughn, Noose Neck, R. I.
75. H. H. Geuchs, Lime Rock, R. I.
76. E. F. Crowninshield, Abbott Run, R. I.
77. Capwell & Tillinghast, Summit, R. I.
78. A. A. Sherman, Daisville, R. I.
79. E. K. Watson, Myatt Point, R. I.
80. Experiment Station, Kingston, R. I.
81. C. P. Chapman, Westerly, R. I.
82. G. A. Tillinghast, Summit, R. I.
83. E. F. Crowninshield, Abbott Run, R. I.
84. H. E. Lewis, Hope Valley, R. I.
85. T. A. H. Teffts, Jamestown, R. I.
86. G. B. Vaughn, Noose Neck, R. I.
87. J. R. Kinerson, Peacham, Vt.
88. Zeno Benson, Bridgewater, Mass.
89. John Labrun, Lee, Mass.
90. Seth H. Rising, West Rupert, Vt.
91. J. M. Manning, Taunton, Mass.

TABLE 25.

Effects of Individual Ingredients of Fertilizers on Corn and Potato Crops with Heavy Loam to Heavy Clay Soils.

Reference No.	LOCALITY.	NITROGEN.			PHOSPHORIC ACID.			POTASH.		
		Plots With.	Plots Without.	Gain or Loss (-).	Plots With.	Plots Without.	Gain or Loss (-).	Plots With.	Plots Without.	Gain or Loss (-).
	Corn. 1878–81.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
1	Putnam, Ct., -	33.4	34.0	-0.6	44.2	19.6	24.6	33.8	33.5	0.3
2	Orono, Me., - -	34.8	33.7	1.1	36.2	31.7	4.5	38.7	28.5	10.2
3	Tunbridge, Vt., -	33.8	32.5	1.3	34.4	31.9	2.5	33.1	33.1	0.0
4	Putnam, Ct., -	25.4	28.7	-3.3	41.4	7.4	34.0	25.6	28.4	-2.8
5	W. Millbury, Mass.,	8.5	9.7	-1.2	13.6	4.6	9.0	10.7	7.6	3.1
6	Bridgewater, Mass.,	25.7	21.6	4.1	28.6	18.8	9.8	21.4	25.9	-4.5
7	E. Shoreham, Vt.,	45.0	41.9	3.1	43.4	43.4	0.0	45.0	41.9	3.1
8	N. Hampt'n, N.H.,	65.9	59.1	6.8	70.3	54.7	15.6	64.0	61.0	3.0
9	Orono, Me., - -	17.3	18.4	-1.1	21.9	12.3	9.6	15.9	20.3	-4.4
10	Putnam, Ct., -	34.8	40.2	-5.4	47.8	22.9	24.9	37.9	36.1	1.8
	Average, 30–39,	**32.5**	**32.0**	**0.5**	**38.2**	**24.7**	**13.5**	**32.6**	**31.6**	**1.0**
	1888–91.									
11	Brooklyn, Ct., -	27.9	29.8	-1.9	35.0	20.3	14.7	30.4	26.4	4.0
12	Putnam, Ct., -	32.0	34.3	-2.3	38.1	26.2	11.9	35.7	29.4	6.3
13	S. Manchester, Ct.,	29.8	29.9	-0.1	37.6	19.4	18.2	30.6	28.8	1.8
14	Lebanon, Ct., -	16.6	18.0	-1.4	20.9	12.4	8.5	16.4	18.4	-2.0
15	N. Woodstock, Ct.,	10.5	13.7	-3.2	17.7	4.2	13.5	10.7	13.5	-2.8
16	Franklin, Ct., -	25.6	28.9	-3.3	30.2	22.8	7.4	25.9	28.5	-2.6
17	Mansfield, Ct., -	34.7	32.7	2.0	35.3	31.9	3.4	33.8	33.9	-0.1
18	Putnam, Ct., -	27.8	27.4	0.4	32.7	20.8	11.9	28.3	30.0	-1.7
	Average, 40–47,	**25.6**	**26.8**	**-1.2**	**30.9**	**19.8**	**11.1**	**26.5**	**26.1**	**0.4**
	Average, (30–47),	**29.4**	**29.2**	**0.2**	**35.0**	**22.5**	**12.5**	**29.9**	**29.2**	**0.7**
	Potatoes. 1878–80.									
19	Calais, Vt., - -	135.3	127.5	7.8	133.5	129.2	4.3	127.8	135.0	-7.2
20	Lunenburg, Vt., -	85.0	65.0	20.0	105.0	45.0	60.0	80.0	70.0	10.0
21	Orono, Me., - -	71.0	64.3	6.7	81.3	54.0	27.3	93.0	42.3	50.7
22	Putnam, Ct., -	69.8	64.3	5.5	91.3	35.7	55.6	70.5	63.3	7.2
23	Mansfield, Vt., -	94.5	92.8	1.7	142.5	44.8	97.7	102.5	84.7	17.8
24	Lunenburg, Vt., -	257.5	225.0	32.5	281.3	201.2	80.1	301.3	181.5	120.0
25	Cabot, Vt., - -	142.5	151.0	-8.5	192.3	101.3	91.0	150.0	143.5	6.5
26	Putnam, Ct., -	120.0	110.0	10.0	124.5	104.0	20.5	119.0	111.3	7.7
27	Falls Village, Ct.,	179.8	195.5	-15.7	200.3	175.0	25.3	197.0	178.3	18.7
	Average, - -	**128.4**	**121.7**	**6.7**	**150.2**	**98.9**	**51.3**	**137.9**	**112.2**	**25.7**

TABLE 26.

Effects of Individual Ingredients of Fertilizers on Corn and Potato Crops, with Sandy to Loam Soil.

Reference No.	LOCALITY.	NITROGEN.			PHOSPHORIC ACID.			POTASH.		
		Plots With.	Plots Without.	Gain or Loss (-).	Plots With.	Plots Without.	Gain or Loss (-).	Plots With.	Plots Without.	Gain or Loss (-).
	Corn.									
	1878–1881.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
28	Irasburgh, Vt., -	21.8	17.3	4.5	20.6	18.4	2.2	26.1	12.9	13.2
29	West Rupert, Vt.,-	51.3	44.1	7.2	48.4	47.1	-1.3	50.7	44.8	5.9
30	Plainfield, Vt., -	39.3	37.5	1.8	41.1	35.7	5.4	35.1	41.7	-6.6
31	Brattleboro, Vt., -	31.6	31.7	-0.1	36.3	32.1	4.1	37.2	31.1	6.1
32	Watertown, Ct., -	43.0	25.9	17.1	45.6	23.2	22.4	47.0	21.8	25.2
33	Taunton, Mass., -	15.7	12.0	3.7	19.3	10.7	8.6	17.2	12.8	4.4
34	Bridgewater, Mass.,	28.0	19.4	8.6	32.3	15.1	17.2	21.1	26.4	-5.3
35	Plymouth, Mass., -	29.7	16.2	13.5	25.2	20.7	4.5	27.5	18.4	9.1
36	Pomfret, Vt., -	31.2	30.8	0.4	33.4	28.7	4.7	30.6	31.5	-0.9
37	Taunton, Mass., -	49.6	54.4	-4.8	57.8	43.6	14.2	53.7	48.9	4.8
38	S. Pomfret, Vt., -	39.7	34.3	5.4	35.5	36.1	-0.6	43.8	30.2	13.6
39	Middletown, Ct., -	52.3	50.3	2.0	48.5	55.4	-6.9	56.0	45.4	10.6
40	Pittsford, Vt., -	59.2	45.2	14.0	49.1	49.6	-0.5	49.5	49.1	0.4
41	Taunton, Mass., -	30.9	22.4	8.5	29.9	23.4	6.5	30.9	22.4	8.5
42	Cheshire, Ct., -	50.9	51.1	-0.2	51.9	50.1	1.8	49.8	52.3	-2.5
43	Middletown, Ct., -	43.1	40.9	2.2	49.8	32.0	17.8	40.3	44.6	-4.3
44	Middleboro, Mass.,	41.3	41.2	0.1	47.4	35.0	12.4	39.5	42.9	-3.4
	Average, - -	**38.7**	**33.8**	**4.9**	**39.5**	**32.9**	**6.6**	**38.6**	**34.0**	**4.6**
	1888–1891.									
	CONNECTICUT.									
45	New Britain, -	34.8	24.8	10.0	27.7	31.0	-3.3	31.6	29.1	2.5
46	Brooklyn, - -	38.9	32.7	6.2	34.7	38.2	-3.5	34.8	38.1	-3.3
47	Falls Village, -	37.1	31.6	5.5	33.5	36.3	-2.8	41.6	25.6	16.0
48	Lime Rock, - -	21.6	15.1	6.5	16.7	20.3	-3.6	20.9	14.7	6.2
49	Oxford, - -	24.6	24.0	0.6	25.6	22.7	2.9	31.2	15.1	16.1
50	New Britain, -	11.0	7.4	3.6	10.2	8.5	1.7	9.5	9.4	0.1
51	Danielsonville, -	19.5	19.0	0.5	25.1	11.6	13.5	23.5	13.6	9.9
52	Falls Village, -	22.8	16.3	6.5	19.1	21.2	-2.1	29.2	7.7	21.5
53	Oxford, - -	24.9	20.3	4.6	24.4	20.9	3.5	30.5	12.8	17.7
54	E. Woodstock, -	54.8	43.3	11.5	49.1	50.8	-1.7	50.4	49.2	1.2
55	Wapping, - -	41.6	37.7	3.9	39.5	40.5	-1.0	45.6	32.4	13.2
56	Canterbury, - -	37.6	21.3	16.3	29.7	31.7	-2.0	32.3	28.3	4.0
	Average, 45–56,	**30.8**	**24.5**	**6.3**	**27.9**	**27.8**	**0.1**	**31.8**	**23.0**	**8.8**
	Average, 28–56,	**35.4**	**29.9**	**5.5**	**34.7**	**30.7**	**4.0**	**35.8**	**29.5**	**6.3**

TABLE 26.—*(Continued.)*

Reference No.	LOCALITY.	NITROGEN.			PHOSPHORIC ACID.			POTASH.		
		Plots With.	Plots Without.	Gain or Loss (–).	Plots With.	Plots Without.	Gain or Loss (–).	Plots With.	Plots Without.	Gain or Loss (–).
	MASSACHUSETTS.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
57	Freetown, - -	29.7	25.2	4.5	30.7	24.2	6.5	27.1	27.9	–0.8
58	Marblehead, -	28.8	23.1	5.7	26.0	26.0	0.0	27.4	24.0	3.9
59	Shelburne, - -	43.7	38.2	5.5	43.0	38.8	4.2	44.7	37.2	7.5
60	Worcester, - -	58.6	53.5	5.1	57.9	54.2	3.7	57.6	54.5	3.1
61	Amherst, - -	47.6	43.7	3.9	48.4	42.8	5.8	57.9	33.4	24.5
62	Marblehead, -	35.7	28.1	7.6	31.6	32.1	–0.5	36.1	27.7	8.4
63	Bridgewater, -	15.3	12.5	2.8	15.5	12.3	3.2	19.4	8.3	11.1
64	Freetown, - -	27.7	21.1	6.6	26.5	22.3	4.2	27.0	21.8	5.2
65	Yarmouth, - -	27.5	23.7	3.8	22.8	28.3	–5.5	27.6	23.6	4.0
66	Worcester, - -	42.8	41.1	1.7	43.7	40.2	3.5	46.0	38.0	8.0
67	Westfield, - -	18.5	12.5	6.0	22.0	8.9	13.1	16.5	14.4	2.1
68	Shelburne, - -	26.6	24.2	2.4	28.7	22.2	6.5	26.4	24.5	1.9
69	Amherst, - -	58.8	61.2	–2.4	63.0	57.0	6.0	67.5	52.5	15.0
70	Sunderland, - -	41.8	39.1	2.7	44.3	36.6	7.7	49.4	31.5	17.9
71	Wilbraham, - -	50.4	39.7	10.7	47.9	42.3	5.6	54.4	35.7	18.7
	Average, - -	**36.9**	**32.5**	**4.4**	**36.8**	**32.5**	**4.3**	**39.0**	**30.3**	**8.7**
	RHODE ISLAND.									
72	Kingston, - -	38.8	41.0	–2.2	40.5	38.7	1.8	44.6	33.2	11.4
73	Hope Valley, -	32.2	32.6	–0.4	33.0	23.6	9.4	33.5	30.8	2.7
74	Noose Neck, -	33.0	29.3	3.7	26.5	34.0	–7.5	29.7	33.8	–4.1
75	Lime Rock, - -	50.4	65.9	15.3	56.7	57.4	–0.7	57.4	56.4	1.0
76	Abbott Run, -	33.3	33.6	–0.3	35.5	30.7	4.8	32.4	34.8	–2.4
77	Summit, - -	26.3	25.4	0.9	31.8	18.1	13.7	27.0	24.5	2.5
78	Dansville, - -	63.5	60.8	2.7	62.9	61.6	1.3	65.1	58.8	6.3
79	Myatt Point, -	48.7	42.4	6.3	43.1	41.8	1.3	43.6	41.2	2.4
80	Kingston, - -	20.2	21.0	–0.8	25.2	14.3	10.9	23.4	16.7	6.7
81	Westerly, - -	34.5	28.4	6.1	37.5	24.3	13.2	34.0	29.1	4.9
82	Summit, - -	25.2	23.9	1.3	38.4	6.2	32.2	25.3	23.7	1.6
83	Abbott Run, -	25.5	21.3	4.2	28.4	18.1	10.3	23.3	24.2	–0.9
84	Hope Valley, -	36.0	22.4	13.6	34.8	24.0	10.8	34.3	24.8	9.5
85	Jamestown, - -	39.4	28.5	10.9	34.1	35.5	–1.4	36.2	32.7	3.5
86	Noose Neck, -	28.8	24.3	4.5	28.2	28.5	–0.3	29.2	23.8	5.4
	Average, - -	**35.7**	**33.4**	**2.3**	**37.1**	**30.5**	**6.6**	**35.9**	**32.6**	**3.3**
	Potatoes. 1878–1880.									
87	Peacham, Vt., -	156.3	154.3	2.0	163.0	145.3	17.7	165.5	142.0	23.5
88	Bridgewater, Mass.,	80.0	69.0	11.0	94.5	54.5	40.0	73.5	75.5	–2.0
89	Lee, Mass., - -	68.5	68.0	0.5	73.0	63.5	9.5	81.0	55.5	25.5
90	West Rupert, Vt., -	117.3	113.8	3.5	107.3	123.8	–16.5	131.3	99.8	31.5
91	Taunton, Mass., -	72.4	59.4	13.0	93.2	38.7	54.5	79.6	52.3	27.3
	Average, - -	**98.9**	**92.9**	**6.0**	**106.2**	**85.2**	**21.0**	**106.2**	**85.0**	**21.2**

CO-OPERATIVE FIELD EXPERIMENTS WITH FERTILIZERS.

BY C. S. PHELPS.

The Station has continued its co-operative field experiments with fertilizers through a fifth year, the general plan being similar to that of former years. The experiments for 1892 have been "Soil Tests," with the exception of one "Special Nitrogen" experiment on oats.

The details of the work were under the care of Mr. Bailey up to July 1st, the time of his resignation as Assistant Agriculturist; since then the writer has had supervision of the work.

The following persons have co-operated in the experiments during the past year:

	POST OFFICE.
R. S. HINMAN,	Stevenson.
WILLIAM CRANE,	Broad Brook.
W. W. GREEN,	Wapping.
M. H. & H. G. SPERRY,	Bolton.
E. A. HOXIE,	Lebanon.
C. H. LATHROP,	North Franklin.
A. B. WEBB,	Brooklyn.
E. T. WHITE,	Pomfret Landing.

In connection with nearly all of the experiments, rainfall records have been kept during the growing season. On page 58 will be found the rainfall records for the six months ending Oct. 31st, for twenty localities in the State.

MOISTURE TESTS OF CORN.

Pounds Required for a Bushel of Dry Shelled Corn.

The percentages of water at harvest in the corn of the different experiments are found to vary considerably. The field weights are not an accurate measure of the feeding value of the crop. The moisture and the proportions of cob to corn vary widely on different fields, but have been found to be fairly uniform on different plots on the same field. Moisture tests of the corn, at the time of harvest, have been made for each experiment in order to find the number of pounds of ears required to make a bushel of dry shelled corn. Samples of the hard ears (good) and of the soft ears and nubbins (poor), representing about an average of the crop, were taken separately. These were partially dried in a warm room, and after the samples had reached about a constant weight, were re-weighed, shelled, and the proportion of corn and cob obtained. Small samples of the grain were then sealed in jars, and taken at once to the laboratory for complete moisture determinations.

TABLE 27.

Percentages of Dry Matter of Corn in Ears (Grain and Cob), and the Number of Pounds of Ears Required for a Bushel of Shelled Corn.

NAME AND LOCALITY.	Water-free Corn in Sample (Ears) at Harvest.		Pounds of Ears at Harvest to Equal 56 lbs. of Shelled Corn, with 11 % Water.	
	Good.	Poor.	Good.	Poor.
	%	%	Lbs.	Lbs.
R. S. Hinman, Stevenson,	61.6	56.1	81	89
William Crane, Broad Brook,	62.8	54.7	80	91
M. H. & H. G. Sperry, Bolton,	63.7	53.6	79	93
E. A. Hoxie, Lebanon,	55.6	48.2	90	104
C. H. Lathrop, North Franklin,	58.7	46.8	85	107
A. B. Webb, Brooklyn,	57.4	48.1	87	104
E. T. White, Pomfret Landing,	61.6	54.6	81	91

From table 27 it will be seen that the percentages of water-free corn on the ears, at the time of harvest, ranged from 55.6 to 63.7 per cent. The differences here shown may be ascribed to two causes, variations in the proportions of cob to corn, and variations in the amounts of moisture contained in the corn. The proportion of cob to corn seems to have the greatest influence over the amount of dry matter of grain in the crop.

The Sperry Brothers grew a variety that "filled out" well, and the proportion of cob was relatively small. Mr. Hoxie's corn was not well filled out, and the relative amount of cob was large. The amount of ears at harvest required to make one bushel of merchantable grain (11 per cent. water), varies from 79 to 90 pounds. From experiments covering three years, it is found that the average weight of corn at harvest required for one bushel of dry shelled corn (11 per cent. water), is 84 pounds. This is from 10 to 15 pounds more than the amount generally estimated by farmers.

From 70 to 75 pounds is commonly considered sufficient to equal a bushel of well dried corn.

SOIL TEST EXPERIMENTS.

The plan of experiments for soil tests consisted in applying, on parallel plots of land, fertilizers containing nitrogen, phosphoric acid, and potash, singly, two by two, and all three together. The fertilizing materials were in all cases supplied by the Station, in standard commercial forms, such as nitrate of soda, sulphate of ammonia, dried blood, dissolved bone-black, and muriate of potash. In all of the experiments here described, the cost of the fertilizer is estimated from the retail selling prices of the materials, plus $2 per ton for mixing and freights.

On the following pages, the comparative yields are shown by means of diagrams. The fertilizers and the weights are given at the left of the diagram. The length of the line represents the comparative yield per acre of shelled corn from the different plots. The figures given in the last column show the number of bushels of shelled corn per acre. At the close of this article will be found a series of tabular statements giving the results in detail. In all cases, the yield of shelled corn per acre is reported on the basis of 11 per cent. water, and the stover on the basis of field weights.

EXPERIMENT BY R. S. HINMAN.

Mr. Hinman's field is located near the Housatonic river. The soil is a light loam, with a sandy to gravelly subsoil, and appears to be river terrace formation. The experiment has been continued through five years with the same order of plots and the same kinds and amounts of fertilizers, with the exception of Plot H.

In table 28 are given the yields of dry shelled corn for the five years through which the experiment has been conducted, together with the average. For the first three years potash had a greater effect on the yields than had the other two ingredients. The results for the past two years indicate that the phosphoric acid in the soil has become greatly reduced where none has been added, so this ingredient has become nearly as essential to the production of a crop on these plots as potash. All three ingredients, nitrogen, phosphoric acid, and potash, have been essential to the production of a fair crop in the past two years. Previous to 1891, nitrogen and potash (Plot E) gave nearly as good results as the complete mixture (Plot G).

In 1890 the difference between these two plots (E and G) was on five bushels, while in 1891 it was 13, and in 1892, 10 bushels.

TABLE 28.

Soil Test with Fertilizers on Corn, During Five Years.

BY R. S. HINMAN, OXFORD.

Plot.	FERTILIZERS PER ACRE.			1888.	1889.	1890.	1891.	1892.	Average.
	Kind.	Lbs. per Acre.	Cost per Acre.						
			$	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
A	Nitrate of Soda, - -	160	3.96	29.4	12.2	8.9	9.1	12.0	14.3
B	Dissolved Bone-black, -	320	4.40	21.9	17.4	12.7	17.8	10.3	16.0
C	Muriate of Potash, - -	160	3.48	25.1	22.5	19.4	18.8	10.4	19.2
D	Nitrate of Soda, - - Dissolved Bone-black, -	160 320	8.48	32.7	15.8	16.9	28.9	16.0	22.1
E	Nitrate of Soda, - - Muriate of Potash, - -	160 160	7.52	3.55	33.3	34.5	27.4	17.3	29.6
O	Nothing, - - - - -	—	—	27.8	12.5	14.4	19.8	20.7	19.0
F	Dissolved Bone-black, - Muriate of Potash, - -	320 160	8.00	37.3	32.0	28.7	27.0	22.9	29.6
G	Nitrate of Soda, - - Dissolved Bone-black, - Muriate of Potash, - -	160 320 160	12.00	42.8	37.1	39.4	40.3	27.5	37.4
H	Plaster, - - - - -	400	1.70	30.6	14.1	14.4	—	—	19.7
I	Complete Fertilizers, varied forms, - - -	600	12.93	44.4	31.1	27.2	35.7	14.1	30.5

Comparative Results with Different Fertilizing Ingredients.

NITROGEN.			PHOSPHORIC ACID.			POTASH.		
Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.
25.9	21.1	4.8	26.3	20.7	5.6	29.0	18.0	11.0

The results indicate that an incomplete fertilizer cannot be economically used for several years without gradually reducing the other ingredients from the soil. Although, perhaps, abundant at first, the unsupplied ingredients become exhausted in time and profitable cultivation is no longer possible. The relative importance of nitrogen, phosphoric acid, and potash, is shown by the following tabulation:

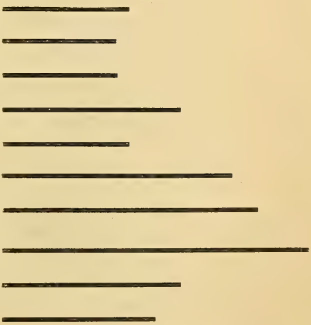
Yields per Acre with and without Different Fertilizing Ingredients.

Nitrogen.			Phosphoric Acid.			Potash.		
Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.
25.9	21.1	4.8	26.3	20.7	5.6	29.0	18.0	11.0

From this it will be seen that potash had the leading effect, while nitrogen and phosphoric acid caused considerable increase. The results for the five years lead to the conclusion that potash needs to be used in quite large quantities for corn on this soil, while nitrogen and phosphoric acid should be more sparingly supplied. The mixture on plot G has given good yields and a financial gain each year, but would very likely be improved by the addition of 50 pounds more of muriate of potash. The small yields obtained on all the plots in 1892, were probably due to the dry season.

SOIL TEST WITH FERTILIZERS ON CORN 1892.

By R. S. HINMAN, Oxford.
(P. O., Stevenson.)

Plot.	Fertilizers.		Yield Shelled Corn Per Acre. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
O.	Nothing, - -	—		12.0
A.	Nitrate of Soda, -	160		10.3
B.	Dis. Bone-black, -	320		10.4
C.	Muriate of Potash,	160		16.0
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320		17.3
E.	Nitrate of Soda. - Muriate of Potash,	160 160		20.7
F.	Dis. Bone-black, - Muriate of Potash,	320 160		22.9
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash,	160 320 160		27.5
H.	Plaster, - -	400		16.3
OO.	Nothing, - -	—		14.1

EXPERIMENT BY WILLIAM CRANE.

The field on which Mr. Crane's experiment was conducted was a "run out" field of nearly level land, that had been alternately cropped and fallowed without the use of manure and with but small quantities of commercial fertilizers. Owing to the size and shape of the field, it was found necessary to extend the last four plots of the experiment (oo, H, G, and F) on to land of a different texture, and which had been differently treated from the rest of the lot. The soil of this portion of the field was lighter in color and appeared to contain less organic matter. It had been planted to beans in 1891, and gave a poor crop. The balance of the field was fallow, and there was upon it a light growth of weeds, which of course added somewhat to the organic matter of the soil and the supply of fertilizers in the crop. For these reasons only the first six plots of the experiment should be considered.

SOIL TEST WITH FERTILIZERS ON CORN.

By WILLIAM CRANE, Ellington.

Plot.	Fertilizers.		Yield Shelled Corn Per Acre. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
O.	Nothing, - -	—		21.2
A.	Nitrate of Soda, -	160		36.3
B.	Dis. Bone-black, -	320		25.7
C.	Muriate of Potash,	160		32.3
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320		37.5
E.	Nitrate of Soda, - Muriate of Potash,	160 160		36.2
F.	Dis. Bone-black, - Muriate of Potash,	320 160		10.8
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash,	160 320 160		20.1
H.	Plaster, - -	400		11.4
OO.	Nothing, - -	—		12.7

From the plots having the fertilizing ingredients supplied singly, (A, B, and C), it will be seen that nitrogen had the leading effect on the crop, potash standing next, while phosphoric acid gave considerable increase over the nothing plot. The results on this part of the experiment seem to indicate that a complete fertilizer containing relatively small quantities of phosphoric acid with liberal proportions of potash and nitrogen, would prove most economical for corn on this soil.

EXPERIMENT BY M. H. AND H. G. SPERRY.

The field selected by the Sperry Brothers was a light loam soil with a sandy subsoil. The land had a gentle slope to the west (the oo side of the field). Plots H and oo were apparently more moist than the remaining plots, and as the season was somewhat dry, these two plots probably gave relatively larger crops than would otherwise have resulted. Owing to the more favorable condition for a good crop found in the soil of plot oo, the increase or decrease over nothing has been compared with plot o.

SOIL TEST WITH FERTILIZERS ON CORN.

By M. W. & H. G. SPERRY, Bolton.

Plot.	Fertilizers.		Yield Shelled Corn Per Acre. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
o.	Nothing, - -	—		52.6
A.	Nitrate of Soda, -	160		58.6
B.	Dis. Bone-black, -	320		52.3
C.	Muriate of Potash,	160		51.5
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320		57.3
E.	Nitrate of Soda, - Muriate of Potash,	160 160		62.8
F.	Dis. Bone-black, - Muriate of Potash,	320 160		53.8
G.	Nitrate of Soda, - Muriate of Potash, Dis. Bone-black, -	160 160 320		64.3
H.	Plaster, - -	400		62.7
oo.	Nothing, - -	—		59.5

The relative results from the use of nitrogen, phosphoric acid, and potash are shown in the following tabulation:

Yields per Acre with and without Different Fertilizing Ingredients.

Nitrogen.			Phosphoric Acid.			Potash.		
Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Loss With.	Plots With.	Plots Without.	Gain With.
60.8	55.1	5.7	56.9	58.9	-2.0	58.1	57.7	0.4

In this experiment nitrogen has had the leading effect. On all of the plots there was considerable increase. This increase was most marked when the nitrogen was combined with potash. The results are in accord with other experiments in this State made on light loam soils. Corn on such soils is generally benefited by potash and nitrogen, while phosphoric acid has a much less effect. The effects of the fertilizers did not appear very marked on any of the plots, probably owing to the fact that a heavy sod was plowed in, which added considerably to the fertility of the soil. The Messrs. Sperry are to continue the experiment through a second year.

EXPERIMENT BY E. A. HOXIE.

Mr. Hoxie's field was part of an old pasture lot that had not been plowed or manured for twenty years. The soil was a light loam, with a sandy to gravelly subsoil. The soil appeared to be fairly uniform, with the exception that a section across one end of the plots was somewhat gravelly. Plot 00 for some unknown reason seemed to be naturally more fertile than the other plots, and as the results were probably abnormal, it has not been included in the tabulation.

Notwithstanding the apparent uniformity of soil just mentioned, the results indicate that this varied considerably in fertility, a condition which may have been due in part to differences in the moisture holding powers of the soil. The portion of the field including plots E, F, and G, was on higher ground and probably was affected by drouth more than other portions of the field. All three ingredients seem to be lacking in this soil.

SOIL TEST WITH FERTILIZERS ON CORN.

By EDWARD HOXIE, Lebanon.

Plot.	Fertilizers.		Yield Shelled Corn Per Acre. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
O.	Nothing, - -	—		21.3
A.	Nitrate of Soda, -	160		30.5
B.	Dis. Bone-black, -	320		24.8
C.	Muriate of Potash,	160		30.6
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320		35.5
E.	Nitrate of Soda, - Muriate of Potash,	160 160		30.7
F.	Dis. Bone-black, - Muriate of Potash,	320 160		34.9
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash,	160 320 160		33.1
H.	Plaster, - -	400		28.7

The relative results from different fertilizing ingredients are shown as follows:

Yields per Acre with and without Different Fertilizing Ingredients.

Nitrogen.			Phosphoric Acid.			Potash.		
Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.
31.5	29.8	1.7	32.1	30.1	2.0	32.4	29.9	2.5

EXPERIMENT BY C. H. LATHROP.

The field selected for Mr. Lathrop's experiment was part of an old meadow that had been mowed and pastured for four years without manure. The land had a gentle slope to the east, and the plots were laid out up and down the slope. The soil is a medium loam, with a yellow, sandy loam subsoil.

SOIL TEST WITH FERTILIZERS ON CORN.

By C. H. LATHROP, North Franklin.

Plot.	Fertilizers.		Yield Shelled Corn Per Acre. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
o.	Nothing, - -	—		34.7
A.	Nitrate of Soda, -	160		39.4
B.	Dis. Bone-black, -	320		42.8
C.	Muriate of Potash,	160		43.8
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320		45.9
E.	Nitrate of Soda, - Muriate of Potash,	160 160		44.2
F.	Dis. Bone-black, - Muriate of Potash,	320 160		40.2
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash,	160 320 160		41.7
H.	Plaster, - -	400		35.0
oo.	Nothing, - -	—		31.6

All three of the essential ingredients seem to be lacking in the soil, as indicated by the increase occurring where these were used singly and in combinations of twos. The reason for the smaller increase on G than on some of the other plots may be accounted for by the dryer condition of the soil on that side of the field.

The relative results from the use of nitrogen, phosphoric acid, and potash are shown in the following tabulation:

Yields per Acre with and without Different Fertilizing Ingredients.

Nitrogen.			Phosphoric Acid.			Potash.		
Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.
42.8	40.5	2.3	42.7	40.6	2.1	42.5	40.8	1.7

EXPERIMENT BY E. T. WHITE.

Mr. White's field was part of an area of "plain land," evidently a terrace formation of the Quinnebaug river. The soil is a sandy loam and the subsoil fine sand. The field had grown corn for three years prior to 1891, with small applications of stable manure. The crop had been good. In 1891 rye was grown, and the field was again sown to rye for the year 1892. The rye was quite uniform and about three inches high when the land was plowed for the experiment.

SOIL TEST WITH FERTILIZERS ON CORN.

By E. T. WHITE, Pomfret Landing.

Plot.	Fertilizers.		Yield Shelled Corn Per Acre. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
O.	Nothing, - -	—		23.9
A.	Nitrate of Soda, -	160		36.1
B.	Dis. Bone-black, -	320		21.6
C.	Muriate of Potash,	160		18.6
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320		30.6
E.	Nitrate of Soda, - Muriate of Potash,	160 160		37.2
F.	Dis. Bone-black, - Muriate of Potash,	320 160		19.8
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash,	160 320 160		31.3
H.	Plaster, - -	400		15.6
OO.	Nothing, - -	—		14.0

The marked increase from the use of nitrogen is quite unusual. Corn as a rule does not respond very markedly to soluble nitrogenous fertilizers. In our experiments on corn the best results with nitrogen in the form of nitrate of soda have been obtained on fine textured, light loam soils.

The tabulation on the next page shows the relative results from the use of the different fertilizing ingredients.

Yields per Acre with and without Different Fertilizing Ingredients.

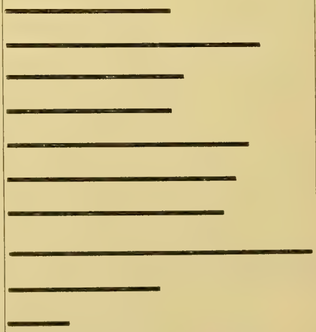
NITROGEN.			PHOSPHORIC ACID.			POTASH.		
Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Loss With.	Plots With.	Plots Without.	Gain With.
33.8	18.9	14.9	25.8	26.9	−1.1	26.7	26.0	0.7

EXPERIMENT BY A. B. WEBB.

The field selected by Mr. Webb was a worn-out alluvial soil near the Quinnebaug river. The soil is a fine light loam, with a subsoil very similar, except there is an absence of organic matter. On the west side (plots G, H, and oo), the soil is much shallower and appeared to be less fertile. The field had been alternated with fallow and buckwheat for several years without the use of manures.

SOIL TEST WITH FERTILIZERS ON CORN.

By A. B. WEBB, Brooklyn.

Plot.	FERTILIZERS.		YIELD SHELLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
O.	Nothing, - -	—		23.1
A.	Nitrate of Soda, -	160		34.1
B.	Dis. Bone-black, -	320		24.9
C.	Muriate of Potash,	160		23.3
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320		32.6
E.	Nitrate of Soda, - Muriate of Potash,	160 160		31.8
F.	Dis. Bone-black, - Muriate of Potash,	320 160		29.2
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash,	160 320 160		39.9
H.	Plaster, - -	400		19.8
OO.	Nothing, - -	—		8.9

Nitrogen seems to be the essential ingredient, although all three ingredients were needed to produce a fair crop. The unusual increase from nitrate of soda alone (Plot A) was probably due to the more fertile condition of the land. This condition was apparent when the field was visited in August, although it could not be accounted for.

The relative results from the three fertilizing ingredients are shown by the following:

Yields per Acre with and without Different Fertilizing Ingredients.

NITROGEN.			PHOSPHORIC ACID.			POTASH.		
Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.
34.6	24.3	10.3	31.7	27.3	4.4	31.1	27.9	3.2

EXPERIMENT BY THE STATION ON OATS.

The oat experiment carried out on the Station land was the third crop in a rotation soil test experiment. The field was planted to corn in 1890, potatoes in 1891, and to oats this year, the order of plots and the fertilizers being the same each season.

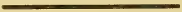
The land was prepared for seeding April 8th, and April 9th was sown with common western oats at the rate of two and one-half bushels per acre. The fertilizer was applied to all of the plots April 14th. The seed germinated well and there was a fairly uniform stand.

Notes were taken several times during the season, and it was noticed that the crop on the plots to which nitrogen had been applied in the fertilizers was in all cases larger and more advanced than where no nitrogen was used. Phosphoric acid also produced considerable effect wherever used, and especially where used with nitrogen, while potash was the least useful. Phosphoric acid appeared to hasten the maturity of the crop. On all plots where this ingredient was used, the oats were in the best condition for cutting from five to seven days earlier than those on plots receiving no phosphoric acid.

It will be seen from table 37 at end of this article that the weights per bushel of grain did not vary greatly. The heaviest oats were not always found on the plots that yielded most. While nitrogen increased the yield considerably, it did not seem to increase the weight per bushel, as will be seen by comparing plots A and G with B and F.

SOIL TEST WITH FERTILIZERS ON OATS.

By THE STATION, Storrs.

Plot.	Fertilizers.		Yield Per Acre. (Grain.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
O.	Nothing, - -	—		29.1
A.	Nitrate of Soda, -	160		36.0
B.	Dis. Bone-black, -	320		27.0
C.	Muriate of Potash,	160		26.3
OO.	Nothing, - -	—		24.2
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320		37.9
E.	Nitrate of Soda, - Muriate of Potash,	160 160		30.0
F.	Dis. Bone-black, - Muriate of Potash,	320 160		27.8
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash,	160 320 160		39.4
OOO	Nothing, - -	—		22.5
X.	Stable Manure, - Dis. Bone-black, -	12,000 160		40.9
Y.	Stable Manure, -	16,000		41.3

The yields of both grain and straw were greatest on the plots to which nitrogen and phosphoric acid were applied, while potash seemed to be of little use. Plot D, with 160 pounds of nitrate of soda and 320 pounds of dissolved bone-black, gave only 1.5 bushels less of oats and 200 pounds less of straw than plot G, which had the same fertilizers with the addition of 160 pounds of muriate of potash. The cost on plot D was $8.48 and on G $12. The experiment illustrates very well the importance of having fertilizers adapted to the needs of the crop and the peculiarities of the soil. Oats are heavy nitrogen feeders, and are, as a rule, greatly benefited by nitrogenous fertilizers. If this point is understood, and then the peculiarities of the soil as regards phosphoric acid and potash are taken into account, fertilizers for the crop may be rationally and economically compounded.

For practical deductions and conclusions from this class of experiments the reader is referred to the summary of field experiments on pages 77-80.

SPECIAL NITROGEN EXPERIMENT ON OATS.

The object of this class of experiments is to study the effect of larger and smaller quantities of nitrogen on different crops, while the amount of mineral fertilizers remains constant. There are two prominent points to be considered: the effect of the fertilizer on the yield, and the effect on the composition and feeding value.

Experiments of this kind have been conducted during the past year on grass and oats. The experiment on grass will be found on pages 36–46 of this Report, and that upon oats by Mr. Green follows.

The field where this experiment is located has been in grass for several years without manure, and yielded less than one ton of hay per acre. The soil is in the red sandstone region of the Connecticut valley, and is a light loam with a subsoil of much the same character to the depth of 2 to 2½ feet. Below this is a medium fine, red sand.

The oats were sown April 15, and the fertilizer was applied and rolled in a few days later.

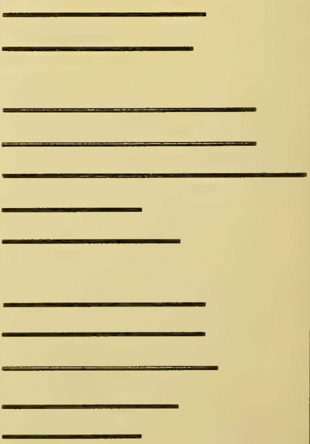
The crop made a fair growth throughout the season, and was not materially injured by blight or drouth. The crop on plots 8 and 9 became lodged quite badly soon after the oats were in blossom. This seems to have checked the development of the grain and reduced the yield beyond what might otherwise have been expected. The weights per bushel were somewhat less on plots 8 and 9 than on plot 7, which would indicate that the crop on these plots failed to mature as fully as on plots where the crop did not lodge.

Plot 0 was on the end of the field nearest the highway, and it seems probable that the land there had not been long under cultivation. The mixed mineral plots gave but little increase over nothing. The average of four mixed mineral plots was 21.3 bushels. The addition of 160 pounds of nitrate of soda to the minerals increased the yield of grain 9 bushels and of straw 675 pounds, at an increased cost of four dollars for the fertilizers. The nitrate of soda gave a much larger increase than dried blood, while the cost of the two mixtures (plots 7 and 13) are practically the same. The extent to which nitrogen can be profitably used is not clearly shown in this experiment, owing to the lodging on plots 8 and 9.

SPECIAL NITROGEN EXPERIMENT ON OATS.

By W. W. GREEN, Wapping.

Plot.	Fertilizers.		Yield Per Acre. (Grain.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
0.	Nothing, - - - - -	—		25.6
6.	Dis. Bone-black, } Mixed Mur. of Potash, } Minr'ls	320 160		23.8
	Nitrate of Soda Group.			
7.	Nitrate of Soda, - - - Mixed Minerals, as 6, -	160 480		30.6
8.	Nitrate of Soda, - - - Mixed Minerals, as 6, -	320 480		30.0
9.	Nitrate of Soda, - - - Mixed Minerals, as 6, -	480 480		35.0
*6*a*	Mixed Minerals, as 6, -	480		17.8
*6*b*	Mixed Minerals, as 6, -	480		21.6
	Dried Blood Group.			
13.	Dried Blood, - - - Mixed Minerals, as 6, -	200 480		25.0
14.	Bried Blood, - - - Mixed Minerals, as 6, -	400 480		25.6
15.	Dried Blood, - - - Mixed Minerals, as 6, -	600 480		26.9
6*c*.	Mixed Minerals, as 6, -	480		21.9
000	Nothing, - - - - -	—		18.1



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* Plots 6*a* and 6*b* were separated by three plots which are not here reported upon.

SOIL TEST WITH FERTILIZERS ON CORN.

TABLE 29.—BY R. S. HINMAN, OXFORD (P. O., STEVENSON).

No. of Plot.	Fertilizers Per Acre.			Yield Per Plot 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % Water.		Stover.	Gain or Loss (-) over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
O.	Nothing, - -	—	—	50	51	101	6.2	5.8	1010	—
A.	Nitrate of Soda, -	160	3 96	34	54	91	4.2	6.1	910	-1.7
B.	Dis. Bone-black, -	320	4 40	44	44	101	5.4	5.0	1010	-1.6
C.	Muriate of Potash, -	160	3 48	76	58	117	9.4	6.6	1170	4.0
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320	8 48	79	67	136	9.7	7.6	1360	5.3
E.	Nitrate of Soda, - Muriate of Potash, -	160 160	7 52	113	59	142	14.0	6.7	1420	8.7
F.	Dis. Bone-black, - Muriate of Potash, -	320 160	8 00	143	46	232	17.7	5.2	2320	10.9
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash, -	160 320 160	12 00	183	43	237	22.6	4.9	2370	15.5
H.	Special Mixture,* -	625	12 28	98	37	185	12.1	4.2	1850	4.3
I.	Complete fertilizer, Varied forms,	600	12 93	81	36	205	10.0	4.1	2050	2.1

* Nitrate of Soda, 75 lbs.; High Grade Blood, 100 lbs.; Dis. Bone-black, 200 lbs.; Muriate of Potash, 250 lbs.

TABLE 30.—BY WILLIAM CRANE, ELLINGTON.

No. of Plot.	Fertilizers Per Acre.			Yield Per Plot 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % Water.		Stover.	Gain or Loss (-) over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
O.	Nothing, - -	—	—	157	15	95	19.6	1.6	950	—
A.	Nitrate of Soda, -	160	3 96	280	12	263	35.0	1.3	2630	19.3
.	Dis. Bone-black, -	320	4 40	194	13	234	24.3	1.4	2340	8.7
C.	Muriate of Potash, -	160	3 48	249	11	297	31.1	1.2	2970	15.3
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320	8 48	290	11	308	36.3	1.2	3080	20.5
E.	Nitrate of Soda, - Muriate of Potash, -	160 160	7 52	283	7	307	35.4	0.8	3070	19.2
F.	Dis. Bone-black, - Muriate of Potash, -	320 160	8 00	70	18	179	8.8	2.0	1790	-6.2
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash, -	160 320 160	12 00	153	9	292	19.1	1.0	2920	3.1
H.	Plaster, - - -	400	1 70	79	14	138	9.9	1.5	1380	-5.6
OO.	Nothing, - -	—	—	82	22	137	10.3	2.4	1370	—

SOIL TEST WITH FERTILIZERS ON CORN.

TABLE 31—BY M. W. & H. G. SPERRY, BOLTON.

No. of Plot.	Fertilizers Per Acre. Kind.	Weight.	Cost.	Yield Per Plot 1-10 Acre. Ears. Good.	Ears. Poor.	Stover.	Yield Per Acre. Shelled Corn. 11 % Water. Good.	Shelled Corn. Poor.	Stover.	Gain or Loss (−) over Nothing Plots
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
O.	Nothing, - -	—	—	400	19	310	50.6	2.0	3100	—
A.	Nitrate of Soda, -	160	3 96	452	13	329	57.2	1.4	3290	6.0
B.	Dis. Bone-black, -	320	4 40	404	11	273	51.1	1.2	2730	−.3
C.	Muriate of Potash, -	160	3 48	395	14	296	50.0	1.5	2960	−1.1
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320	8 48	440	15	310	55.7	1.6	3100	4.7
E.	Nitrate of Soda, - Muriate of Potash, -	160 160	7 52	484	14	335	61.3	1.5	3350	10.2
F.	Dis. Bone-black, - Muriate of Potash, -	320 160	8 00	410	18	316	51.9	1.9	3160	1.2
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash, -	160 320 160	12 00	493	18	395	62.4	1.9	3950	11.7
H.	Plaster, - - -	400	1 70	480	18	352	60.8	1.9	3520	—
OO.	Nothing, - -	—	—	440	35	306	55.7	3.8	3060	—

TABLE 32.—BY EDWARD HOXIE, LEBANON.

No. of Plot.	Fertilizers Per Acre. Kind.	Weight.	Cost.	Yield Per Plot 1-10 Acre. Ears. Good.	Ears. Poor.	Stover.	Yield Per Acre. Shelled Corn. 11 % Water. Good.	Shelled Corn. Poor.	Stover.	Gain over Nothing Plots.
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
O.	Nothing, - -	—	—	157	40	230	17.4	3.9	2300	—
A.	Nitrate of Soda, -	160	3 96	247	31	252	27.4	3.1	2520	9.2
B.	Dis. Bone-black, -	320	4 40	200	27	251	22.2	2.6	2510	3.5
C.	Muriate of Potash, -	160	3 48	241	38	260	26.8	3.8	2600	9.3
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320	8 48	284	40	263	31.6	3.9	2630	14.2
E.	Nitrate of Soda, - Muriate of Potash, -	160 160	7 52	236	46	279	26.2	4.5	2790	9.4
F.	Dis. Bone-black, - Muriate of Potash, -	320 160	8 00	270	50	301	30.0	4.9	3010	13.6
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash, -	160 320 160	12 00	249	56	319	27.7	5.4	3190	11.8
H.	Plaster, - - -	400	1 70	212	53	245	23.6	5.1	2450	7.4
OO.	Nothing, - -	—	—	—	—	—	—	—	—	—

SOIL TEST WITH FERTILIZERS ON CORN.

Table 33.—By C. H. LATHROP, North Franklin.

No. of Plot.	Fertilizers Per Acre.			Yield Per Plot 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % Water.		Stover.	Gain over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
O.	Nothing, - -	—	—	281	17	190	33.1	1.6	1900	—
A.	Nitrate of Soda, -	160	3 96	327	10	219	38.5	0.9	2190	6.2
B.	Dis. Bone-black, -	320	4 40	350	17	225	41.2	1.6	2250	9.6
C.	Muriate of Potash, -	160	3 48	366	7	257	43.1	0.7	2570	10.6
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320	8 48	379	14	290	44.6	1.3	2900	12.7
E.	Nitrate of Soda, - Muriate of Potash, -	160 160	7 52	362	17	287	42.6	1.6	2870	11.0
F.	Dis. Bone-black, - Muriate of Potash, -	320 160	8 00	338	4	274	39.8	0.4	2740	7.0
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash, -	160 320 160	12 00	347	10	307	40.8	0.9	3070	8.5
H.	Plaster, - - -	400	1 70	292	6	211	34.4	0.6	2110	1.8
OO.	Nothing, - -	—	—	257	15	218	30.2	1.4	2180	—

Table 34.—By E. T. WHITE, Pomfret Landing.

No. of Plot.	Fertilizers Per Acre.			Yield Per Plot 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % Water.		Stover.	Gain or Loss (-) over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
O.	Nothing, - -	—	—	185	10	209	22.8	1.1	2090	—
A.	Nitrate of Soda, -	160	3 96	291	2	211	35.9	.2	2110	17.1
B.	Dis. Bone-black, -	320	4 40	169	6	160	20.9	.7	1600	2.6
C.	Muriate of Potash, -	160	3 48	148	3	186	18.3	.3	1860	-.4
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320	8 48	245	4	281	30.2	.4	2810	11.6
E.	Nitrate of Soda, - Muriate of Potash, -	160 160	7 52	296	6	237	36.5	.7	2370	18.2
F.	Dis. Bone-black, - Muriate of Potash, -	320 160	8 00	157	4	214	19.4	.4	2140	.8
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash, -	160 320 160	12 00	248	6	234	30.6	.7	2340	12.3
H.	Plaster, - - -	400	1 70	122	5	173	15.1	.5	1730	-3.4
OO.	Nothing, - -	—	—	110	4	135	13.6	.4	1350	—

SOIL TEST WITH FERTILIZERS ON CORN.

TABLE 35.—BY A. B. WEBB, BROOKLYN.

No. of Plot.	Fertilizers Per Acre.			Yield Per Plot 1-10 Acre.			Yield Per Acre.			
	Kind.	Weight.	Cost.	Ears. Good.	Ears. Poor.	Stover.	Shelled Corn. 11 % Water. Good.	Shelled Corn. 11 % Water. Poor.	Stover.	Gain over Nothing Plots.
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
O.	Nothing, - -	—	—	170	37	324	19.5	3.6	2340	—
A.	Nitrate of Soda, -	160	3 96	278	22	350	32.0	2.1	3500	18.1
B.	Dis. Bone-black, -	320	4 40	183	41	275	21.0	3.9	2750	8.9
C.	Muriate of Potash, -	160	3 48	149	64	295	17.1	6.2	2950	7.3
D.	Nitrate of Soda, - Dis. Bone-black, -	160 320	8 48	234	59	273	26.9	5.7	2730	16.6
E.	Nitrate of Soda, - Muriate of Potash, -	160 160	7 52	219	69	311	25.2	6.6	3110	15.8
F.	Dis. Bone-black, - Muriate of Potash, -	320 160	8 00	211	52	340	24.2	5.0	3400	13.2
G.	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash, -	160 320 160	12 00	310	45	417	35.6	4.3	4170	23.9
H.	Plaster, - - -	400	1 70	114	70	224	13.1	6.7	2240	3.8
OO.	Nothing, - -	—	—	48	35	118	5.5	3.4	1180	—

SOIL TEST WITH FERTILIZERS ON OATS.

TABLE 36.—BY THE STATION, STORRS.

No. of Plot.	Fertilizers Per Acre.			Yield Per Plot. 1-12 Acre.		Yield Per Acre.			
	Kind.	Weight.	Cost.	Oats.	Straw.	Oats.	Straw.	Gain over Noth'g Plts.	Weight per Bushel.
		Lbs.	$	Lbs.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
O.	Nothing, - - - -	—	—	75	105	29.1	1260	—	30.9
A.	Nitrate of Soda, - -	160	3 96	90	140	36.0	1680	10.7	30.0
B.	Dis. Bone-black, -	320	4 40	72	117	27.0	1404	1.7	32.0
C.	Muriate of Potash, -	160	3 48	66	102	26.3	1224	1.0	30.1
OO.	Nothing, - - -	—	—	63	93	24.2	1116	—	31.2
D.	Nitrate of Soda, - - Dis. Bone-black, -	160 320	8 48	102	167	37.9	1998	12.6	32.2
E.	Nitrate of Soda, - - Muriate of Potash, -	160 160	7 52	80	145	30.0	1740	4.7	32.0
F.	Dis. Bone-black, - Muriate of Potash, -	320 160	8 00	76	120	27.8	1434	2.5	32.6
G.	Nitrate of Soda, - - Dis. Bone-black, - Muriate of Potash, -	160 320 160	12 00	105	182	39.4	2184	14.1	32.0
OOO.	Nothing, - - -	—	—	61	87	22.5	1044	—	32.5
X.	Stable Manure, - - Dis. Bone-black, -	12000 160	18 80	106	177	40.9	2124	15.6	31.1
Y.	Stable Manure, - -	16000	19 20	114	187	41.3	2244	16.0	33.1

TABLE 37.

SPECIAL NITROGEN EXPERIMENT ON OATS.

BY W. W. GREEN, WAPPING.

No. of Plot.	Fertilizers Per Acre.			Yield Per Plot 1-10 Acre.		Yield Per Acre.			
	Kind.	Weight.	Cost.	Oats.	Straw.	Oats.	Straw.	Gain or Loss over Nothing Plots.	Weight per Bushel.
		Lbs.	$	Lbs.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
0	Nothing, - - -	—	—	71	155	25.6	1550	—	27.7
6	Dis. Bone-black, Mixd Mur. of Potash, Minls	320 160	8 00	62	146	23.8	1460	1.9	26.1
	Nitrate of Soda Group.								
7	Nitrate of Soda, - - Mixed Minerals, as 6, -	160 480	12 00	89	210	30.6	2100	8.7	29.1
8	Nitrate of Soda, - - Mixed Minerals, as 6, -	320 480	15 96	85	220	30.0	2200	8.1	28.3
9	Nitrate of Soda, - - Mixed Minerals, as 6, -	480 480	19 92	90	345	35.0	3450	13.1	25.7
6*a**	Mixed Minerals, as 6, -	480	8 00	49	158	17.8	1580	-4.1	27.5
6*b**	Mixed Minerals, as 6, -	480	8 00	60	144	21.6	1440	-0.3	27.8
	Dried Blood Group.								
13	Dried Blood, - - - Mixed Minerals, as 6, -	200 480	11 95	73	201	25.0	2010	3.1	29.2
14	Dried Blood, - - - Mixed Minerals, as 6, -	400 480	15 90	76	258	25.6	2580	3.7	29.7
15	Dried Blood, - - - Mixed Minerals, as 6, -	600 480	19 85	78	265	26.9	2650	5.0	29.0
6*c*	Mixed Minerals, as 6, -	480	8 00	63	122	21.9	1220	0	28.8
000	Nothing, - - -	—	—	52	109	18.1	1090	—	28.7

* Plots 6*a* and 6*b* were separated by three plots which are not reported upon.

BACTERIA IN THE DAIRY.*

BY H. W. CONN.

IV. THE ISOLATION OF RENNET FROM BACTERIA CULTURES.

Ever since the beginning of the study of micro-organisms it has been a debated question whether fermentations are to be regarded as purely biological or purely chemical phenomena, or as partaking of both characters. Beginning with the work of Schwann and others in the early part of the century, careful experimentation, aided by microscopic study, seemed to point to a biological explanation of nearly all forms of fermentation which had hitherto been considered as purely chemical. The work of the third and fourth decades of the century proved beyond question that most fermentations were always intimately associated with the growth of micro-organisms, and the inference was a natural one that the micro-organisms themselves were the cause of the fermentations. Shortly after the valuable work of Schwann had started this thought, appeared the brilliant investigations and discussions of Liebig upon fermentations in general. By Liebig all fermentations were regarded as purely chemical phenomena, and the presence of micro-organisms was regarded only as a concomitant incident. By him all albuminous matter was supposed to tend spontaneously toward decomposition, and such decomposition was the basis of fermentation and decay. This, the chemical theory, was for twenty years the favorite. The biological and chemical theories were at that time very rigidly opposed to each other and supposed to be contradictory. The brilliancy of the exposition of the chemical theory by Liebig resulted in its almost universal acceptance for twenty years, and it was not until the genius of Pasteur was directed toward fermentation that a succession of brilliant experiments finally settled the question as to

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*During the past five years investigations on the Bacteria of Milk have been conducted in behalf of the Station by H. W. Conn, Professor of Biology in Wesleyan University. Some of the results have been given in the publications of the Station, as follows: *Bacteria in Milk, Cream, and Butter*, Bulletin 4, and Annual Report for 1889, pp. 52–67. *Ripening of Cream*, Annual Report for 1890, pp. 136–157. *A Micrococcus of Bitter Milk*, Report for 1891, pp. 158–162.

the real relation of organisms to various forms of fermentation, and proved that albuminous matter has in itself no tendency toward decomposition. Pasteur, as every one knows, by excluding all sources of error from his experiments, succeeded in practically disproving the old ideas of spontaneous generation, and in demonstrating, also, that at least a majority of forms of fermentations are caused by micro-organisms. From the time when Pasteur turned his attention to the subject the drift of research and thought was reversed; experimenter after experimenter succeeded in confirming the views of Pasteur, until at last the conclusion was demonstrated beyond peradventure that nothing will undergo fermentation of itself and that most of the forms of fermentations occur only through the influence of bacteria or yeasts.

This explanation, however, was soon seen to be only a partial one; for while it was conclusively demonstrated that micro-organisms produced the fermentations, it still remained a question as to *how* they produced these results. There arose consequently, a number of distinct theories as to the method of these fermentations, the chief of which were the following: The theory of Pasteur regarded certain forms of fermentation which he had studied, as purely biological phenomena, and described them as due to growth without oxygen. In general, this theory assumed that the micro-organisms growing in solutions in which they found no free oxygen, seized oxygen from the molecules of the fermentable material and thus caused a degradation of those molecules which resulted in fermentation. Where plenty of free oxygen was present, other types of chemical change occurred producing putrefactions. A second theory, that of Nägeli, attributed the phenomena to a phase of molecular physics, assuming that certain forms of molecular vibration, which were developed during the growth of the micro-organisms, were transferred to the fermentable material, and this molecular vibration caused the degradation of the fermentable molecules. A third theory was the chemical theory. In accordance with this, the fermentations are, in reality, chemical actions, and produced by certain products of bacteria growth. This last theory has been proved to be true in some cases, and requires further explanation.

In the early study of fermentations, a confusion of ideas naturally led to no clear distinction between different types of fermentation. It was in 1854 that Schroeder and Dusch (An.

d. Chem. u. Pharm., 89, 232) first suggested that fermentations might be divided into two somewhat distinct classes, finding that in some cases the fermentative action was checked by reagents like glycerine, which destroyed organic life, while in other cases the fermentation was not checked by these reagents. This was the first suggestion of a distinction between what we now recognize as organized and unorganized ferments. In later years this distinction has been more clearly drawn, and to-day chemists and biologists everywhere recognize a radical difference between these two forms of fermentation. On the one hand, we have such ferments as are produced by the digestive glands, ptyalin, pepsin, trypsin, rennet, etc., which are not organized, do not grow, and seemingly act by purely chemical means. These ferments are called *enzymes*. On the other hand, we have fermentations, such as those produced by the alcoholic ferments and lactic ferments of milk, which are produced by micro-organisms and only occur when these micro-organisms grow and multiply in the fermentable material. But while we recognize these two distinct types of ferments, it must be admitted that as yet neither the chemists nor the biologists really understand the method of action in either case. The unorganized ferments produce chemical action in the fermentable material, but why they do this and what is the source of energy for the action we do not understand. The organized ferments also produce chemical changes in the fermentable materials, doing so only when growing, but how they produce these changes is equally uncertain.

In recent years there has been a tendency in biological research to show that the two forms of fermentations are, at least in some cases, very closely allied. Certain forms of fermentations, produced by micro-organisms, seem to be identical in their chemical nature with those produced by some unorganized ferments. Various facts have raised the question whether it is not possible that the micro-organisms produce unorganized ferments or enzymes as a result of their growth, perhaps as excretions, and that the immediate cause of the fermentation in these cases is the action of the enzymes, and thus is chemical rather than biological.

The first suggestion in this line resulted from the study of germ diseases, and the gradual development of the theory that the immediate causes of these diseases are certain poisons secreted by the growing bacteria, and known in general as *ptomaïnes*. These ptomaïnes are certainly produced by the disease germs growing in the body, and being extremely virulent poisons act in a deleterious manner upon the tissues of the organisms and give rise to the abnormal symptoms. These ptomaïnes have been studied for some ten years or more. They have been isolated in many cases from bacteria cultures and their direct actions on the animal body determined by experiment. There is no question that it is to these ptomaïnes that the deleterious action of bacteria is due, at least in many germ diseases.

In the study of fermentations proper evidence has begun to accumulate in recent years that the immediate cause of the action is, in some cases at least, the production of chemical enzymes. Even as long ago as 1876 it had been pointed out by Pasteur and Joubert (Comp. rend., 1876), that the fermentation of urea into ammonium carbonate was probably produced by a chemical enzyme. In the last ten years a number of investigators, Arloing, Baginsky, Beyerinck, Brunton and Macfadyen, Salkowski, Vignal, Wood, Wortmann, and Hueppe have been convinced by experiments that other organic fermentations, such as the liquefaction of gelatine, the diastatic fermentation, the inversion of sugar by bacteria growth, etc., are in a similar way caused immediately by *unorganized* ferments, which the bacteria have produced. Finally, in 1890, Fermi succeeded for the first time in definitely isolating from bacteria cultures a chemical enzyme which possesses powers quite similar to those of trypsin produced from the pancreas, and is doubtless the cause of the liquefaction of gelatine by bacteria. This enzyme from bacteria cultures peptonizes albuminoids, and in all essential respects, so far as made out by Fermi, agrees with trypsin in its characteristics.

One of Pasteur's first subjects for study was the fermentations of milk, and one of his first successful experiments consisted in the demonstration that milk fermentations are wholly due to the growth of micro-organisms. Pasteur quite early succeeded in discovering that the fermentations which take place in milk are not always alike, but while he distinguished between the lactic acid fermentations and the butyric acid fermentations the difficulties of experiment were so great that no clear classification of milk fermentations was then possible. For twenty years after the publication of Pasteur's first work on milk very little advance on this subject was made. In 1882 Duclaux (Ann. d. l'Inst. Nat. Agronomique, No. 8, 1882-83) pointed out that while the normal fermentations in milk produce lactic acid, and thus render the reaction of milk acid, under certain conditions, milk will curdle but remain neutral or even become weakly alkaline. This was more likely to occur when milk curdled after being boiled. The curdling of milk under these conditions could not, of course, be due to the precipitation of casein by acid, and for the lack of any better explanation Duclaux attributed the action to the formation by the bacteria growing in the milk of a chemical enzyme having the characteristics of rennet. Two years later Hueppe (Mith. a. d. Kaiserl. Gesundsheitsamte, 2, 1884) in his classical study on milk fermentations obtained the same results, so far as concerned an alkaline curdling of milk under the influence of certain species of bacteria, and stated that he was also inclined to accept the explanation of Duclaux that the bacteria in question produced a rennet-like ferment. Hueppe was able to offer no experimental evidence for this conclusion. Later, Warrington studying the same subject, also found the alkaline curdling common to many species of bacteria, and noticed that the species of bacteria, which curdle milk and render it alkaline, have the further characteristic of dissolving or peptonizing the curd by their subsequent growth. This peptonizing of the curd he thought must be due to a ferment having the characteristics of trypsin, and inasmuch as trypsin does not have the power to precipitate casein, concluded that these bacteria produce two enzymes, one having the characteristics of trypsin and the other those of rennet.

From this time on, the recognition of the production of a rennet by some species of bacteria has been quite general on the part of bacteriologists who have studied milk problems. The scores of species of bacteria, whose action on milk has been studied, have been classified into various physiological groups, and one of the most prominent of these groups is one which is supposed to produce a rennet-like ferment and to curdle milk by its action. In general, it has been found that the species which produce this rennet also produce the peptonizing ferment, and consequently have the power both of liquefying gelatine and of dissolving the curd of milk after the casein is precipitated. The reverse of this has not seemed, however, to be true, for not all of the species which produce the peptonizing ferment appear to produce the rennet ferment. There have been found, by Adametz (Oester. Monatsh. f. Thierheilk. und Thierzucht, 1890), and also by the author (An. Rep. of Storrs School Station, 1890), a few species of bacteria which seem to have the peptonizing power without the power of curdling milk. Under their influence milk is slowly peptonized and rendered transparent, but does not enter into a previous solid or gelatinous condition. In one case it was found that a species of bacteria, which at the outset both curdled the milk by the production of a rennet ferment and subsequently peptonized it, after a long continued cultivation lost the curdling power while retaining the peptonizing power, seeming to indicate that the power of producing rennet had disappeared with cultivation at warm temperature. Further, quite a number of species produce both curdling and peptonizing at low temperature (20° C.), while at higher temperatures (37° C.) only the latter occurs.

Up to the present time no one has ever succeeded in demonstrating the presence of this enzyme rennet by isolating it from bacteria cultures. The work of Fermi on the tryptic ferment produced by micro-organisms was confined wholly to the study of the peptonizing enzyme, although his method of experimentation must doubtless have given him a mixture of the two forms of ferment. His experiments, however, were not designed to indicate the presence of the rennet ferment, and he therefore obtained no evidence of its production.

During the last year some experiments in my laboratory have been directed to this problem, and I have finally succeeded in isolating the rennet ferment, although I have not yet obtained it in a pure condition. The species of bacteria which were used as the basis of the experiments were normal milk bacteria obtained from the cream of a neighboring creamery. From the many species obtained from such ripening cream, there were selected a few forms which seemed to have this rennet producing power well developed, and further experiments with these organisms were conducted as shown in the following pages. The species of bacteria used had the following characteristics:

BACILLUS No. 5.

Morphology. A short, oval bacillus with a capsule, and showing bipolar staining. Somewhat variable in size and smaller in agar and potato than in gelatine. No spore formation seen.

Motility. Rapid motion.

Temperature. Will hardly grow in 37° C. Grows best at about 20° C.

Need of Oxygen. Will not grow under mica.

Plate cultures. A small white colony with dark centre. Soon sinks in a pit and rapidly liquefies.

Gelatine tube. Grows rapidly and produces a rather narrow funnel with a thick tenacious scum on the surface, showing a tendency to become cracked. Later the liquid becomes green, and finally yellow and slimy.

Agar. Agar turned greenish. A thin, rough layer grows along inoculation line which is marvelously sticky, almost like thick glue; so thick indeed, that it can hardly be picked up with the needle.

Potato. Brownish yellow growth, quite abundant. Potato discolored in vicinity of the streak.

Milk. At temperature of the room it becomes curdled in two days. Curd soft and slimy with little whey. Reaction alkaline. At 35° C. curdling occurs in six days. Curd subsequently digests into a lemon yellow liquid with sickish odor. Hardly any digestion at 35° C. After four months' cultivation the power of curdling milk was lost, while digestive power was retained and the liquid formed by the digestion was not yellow.

Bouillon. Produces a thick scum with clear liquid. Scum sinks on being disturbed. Later the liquid becomes slimy and cloudy.

BACILLUS No. 6.

Morphology. A short oval rod, almost a micrococcus.

Motility. Is not motile.

Temperature. Grows well at 35° C., and also at 20° C. The growth is less rapid at 35° C. and the yellow pigment does not form.

Need of Oxygen. Will not grow under mica.

Plate cultures. Produces a small round yellow colony which sinks into a pit. The colony has a dark centre with a tendency to concentric rings and radial fractures.

Gelatine tube. Gelatine slowly liquefies with a scum on the surface.

Agar. A thin, white, abundantly spreading growth.

Potato. An abundant, thick-raised irregular mass producing a yellow pigment.

Milk. At the temperature of the room a soft coagulum is formed with a neutral reaction, which later becomes alkaline. At 35° no coagulum. The milk becomes digested into a cloudy but transparent blueish liquid with an aromatic and not disagreeable odor. Reaction of the liquid is alkaline. At 35° C. the digestion occurs without previous curdling.

Bouillon. A slight growth giving rise to a clear liquid with a slight precipitate. Liquid later becoming cloudy.

BACILLUS No. 8.

Morphology. Short rods which never form into chains. Spores produced in abundance.

Motility. Is motile.

Temperature. Growth about equally good at 20° and 35°.

Need of Oxygen. Grows well under mica.

Gelatine tube. Grows rapidly, producing a slender narrow funnel, which later broadens out as the gelatine becomes completely liquefied. After complete liquefaction, which requires about two weeks, the gelatine begins to turn red and in a few days becomes a blood red color.

Agar. A thin, white, smooth, spreading growth, not very abundant.

Potato. A thin, smooth glistening grayish white mass, slightly tinged with brown.

Milk. Milk becomes curdled into a soft mass with neutral reaction in 24 to 48 hours, at the temperature of 20° C. or at 35° C. Later becomes red.

Bouillon. A cloudy liquid produced with sediment.

This organism somewhat resembles B. lactis erythrogenes, but differs from it in its motility and its growth on agar.

BACILLUS No. 9.

Morphology. A slender rod provided with a capsule. More slender when growing in potato than in gelatine. In gelatine there is a tendency toward a bipolar stain, which does not appear in the organism when growing in potato.

Motility. Is very active.

Need of Oxygen. Will not grow under mica.

Gelatine tube. Grows rapidly, liquefies the gelatine; forming at first a very shallow pit, which becomes deepened as the gelatine liquefies.

Agar. Produces a thin, spreading growth, which at first is hardly visible, but later becomes thick and white.

Potato. A thin, grayish, glistening mass, spreading diffusely over potato surface.

Milk. Milk is curdled in the room into a soft mass with neutral reaction. At 35° C. the curdling does not take place. By later growth the curd is digested in the room, and at 35° C. the digestion takes place without the previous curdling.

BACILLUS No. 10.

Morphology. A rod three times as long as broad, showing uniform stain, with no tendency to form chains. In potatoes the rods are more slender and longer than in gelatine. No spore formation observed.

Temperature. Grows well at 35° C. and also at 20° C.

Need of Oxygen. Will not grow under mica.

Gelatine tube. Liquefies, forming a very thin shallow pit, which deepens into a uniform layer in liquid gelatine. After a few days gelatine becomes greenish.

Agar. A thin, transparent, white, spreading growth.

Potato. A thin, grayish layer spreading over potato surface.

Milk. Milk is curdled readily at the temperature of the room and also at 35° C. Coagulum is soft and has a neutral reaction. Later it becomes digested by the further action of the organism, both at 35° C. and at 20° C.

BACILLUS No. 31.

Morphology. Slender short rods showing a bipolar stain. When growing in bouillon, the bipolar stain is not seen. No spore formation observed.

Need of Oxygen. Will not grow under mica.

Colony. A small, rounded, granular colony, which sinks into a liquefied pit.

Gelatine. A shallow funnel, which rapidly liquefies.

Agar. A rather thin, whitish growth along the needle track, which later becomes quite thick. Does not spread very widely.

Potato. A thick, solid growth of a salmon yellow color; later becoming deep salmon and very thick.

Milk. Milk becomes alkaline and transparent. No curdling takes place, but the digestion of the peptone seems to go on in a normal manner. Sometimes at the temperature of the room a curdling occurs previous to digestion.

Bouillon. A flocculent, cloudy mass, collecting at the top and bottom of the liquid, with a clear space between.

BACILLUS No. 32.—*(Bacillus flourescens liquefaciens.)*

Morphology. A small, short rod, sometimes forming chains in bouillon. Slightly longer in bouillon than in gelatine or on potato.

Need of Oxygen. Aerobic.

Temperature. Grows either at 20° C. or at 35° C., but growth is less abundant at 35° C.

Plate culture. A small, rapidly liquefying pit, surrounded by green flourescence.

Agar. A thick white, smooth growth on the surface, turning the agar greenish.

Potato. A thick, moist layer, with a tinge of salmon color.

Milk. At the temperature of the room a very slight, slimy curd is produced in one or two days, which is followed rapidly by a complete digestion, turning the milk into a semi-transparent mass with the characteristic green color. At 35° C. the curdling did not make its appearance, although the milk became digested in the usual manner.

Bouillon. An abundant growth, tingeing the whole bouillon with olive green.

With these organisms, experiments have been carried on as follows:

EXPERIMENT I.

The first problem that presented itself was to determine whether a soluble ferment was formed by the bacteria cultures. For this purpose one of the organisms, No. 5, was inoculated into an Erlenmeyer's flask containing sterilized milk. In this the bacteria were allowed to grow for nine days at the normal temperature of the room (about 20°). At the end of that time the milk had become curdled by the action of the rennet, and the curd was partially dissolved. A small amount of water was then added to the culture in order to make the amount of liquid a little greater and to assist in the solution of the enzymes and render filtration easier, and then the whole was filtrated through a porcelain cylinder. There was obtained a clear, slightly colored filtrate. A small amount of this filtrate was put into a test tube containing sterilized milk and the tube placed in a culture oven at a temperature of 37° C. The milk in the tube became curdled in less than two hours. A gelatine culture was then made from the curdled milk in order to determine whether by any accident the filters had not worked successfully and the bacteria had found their way into the filtrate. The gelatine culture showed no growth, and thus it was demonstrated that the curdling in this case must have been due to some soluble ferment in the filtrate. Parallel with this experiment, a second was conducted in a similar way, except that the organism was cultivated in beef peptone bouillon instead of milk. The filtrate from this culture obtained from the porcelain cylinder did not, in the first experiment, show any power to curdle milk.

EXPERIMENT 2.

Having thus shown the presence of a soluble enzyme in the filtrate, the next problem was to isolate it from its solution. For this purpose the same organism was again cultivated in sterilized milk, filtered at the end of two weeks through a porcelain cylinder, and the filtrate treated with a large amount of strong alcohol. There appeared an abundant precipitate. The precipitate was then allowed to stand under the alcohol for two weeks in a closely stoppered bottle. At the end of that time the precipitate had settled to the bottom of the alcohol and the alcohol was easily decanted from it, leaving the clear precipitate at the bottom. This precipitate was then dissolved in sterilized water. The precipitate dissolved completely. A small amount of this solution was then added to a test tube of sterilized milk and placed at 37° C. The milk was curdled in one and one-half hours. The curdled milk was allowed to stand at 37° C. for two days, to see if the curd became digested. No digestion of the curd made its appearance. The rest of the water solution was again treated with alcohol, which once more precipitated the enzyme. The alcohol was then filtrated off and the precipitate collected and dried. It was thus obtained in the form of a grayish, hard mass, which was found to still retain the power of curdling milk when dissolved in water. This material was kept for several weeks in the laboratory and tested at intervals with like results. The curdling of the milk under the influence of the material was rather slow, requiring several hours' action, and from this the conclusion was reached that the rennet existed in this precipitate only in small quantities and by no means in a pure state.

Having thus obtained a rennet enzyme from one organism, similar experiments were made with the other species in the above list. No. 10 was treated in the same way, but proved to be a slower growing organism and required a longer time for successful experiment. After a cultivation of six weeks, however, it was found possible to obtain rennet from the culture, but in rather small quantity. In the same way the species, Nos. 6, 8, 9, 12, 31, and 32, were experimented with, cultures being made in all cases in milk, and in all cases it was possible to obtain by the method above described a certain amount of rennet ferment from the culture after the organism had grown in it for a proper length of time.

The experiments upon these organisms, however, showed considerable variation in the amount of the precipitate which was obtained by the use of alcohol, and more particularly in the readiness with which this precipitate would coagulate milk. After several experiments it was found that Nos. 8 and 9 produced rennet in the greatest quantity and most rapidly, and these two species were therefore used primarily in all of the following experiments. It was plain from the various sets of experiments that the precipitate obtained from alcohol was by no means pure rennet, but contained in addition the tryptic ferment studied by Fermi, and not unlikely other impurities. Fermi isolated his enzyme by alcohol in a method similar to that described above. The next problem that arose, therefore, was to separate the two ferments from each other, if possible. This, however, has proved to be an extremely difficult and thus far impossible task. Both are soluble in the same materials and both ferments obey essentially the same chemical laws. After some experiments I finally adopted the method of separation of rennet originally employed by Blumenthal, which consisted in the precipitation of the rennet by an excess of common salt. In the isolation of rennet from the gastric secretions, this method has proved to be successful in separating rennet from all traces of pepsin, and my first experiments with the method seemed to indicate that it was also capable of separating the two ferments present in my solutions. Later experiments, as will be shown below, have indicated that the separation of the two ferments by this method is by no means complete, but still the method does partially separate them.

From a large number of experiments upon the organisms I selected a few for description.

EXPERIMENT 3.

Organism 9 was inoculated into flasks of sterilized milk and allowed to grow for fourteen days. By this time the digestion of the casein had been largely affected, and after adding a little water to the culture, the whole was filtered through a porcelain cylinder. The filtrate by experiment was found to be active in its curdling power. The filtrate was then acidified very slightly with an extremely weak solution of $H_2 SO_4$, and then there was added to the solution common salt in large quantities, until there was an excess of salt. When the solution had reached about its limit of dissolving the salt there began to appear a brownish precipitate, which collected on the surface of the liquid instead of sinking to the bottom. This precipitate was removed with a spatula and with a filter and then dissolved in a small quantity of water. The solution was once more acidified with $H_2 SO_4$, and again treated with salt to saturation. The precipitate made its reappearance floating on the surface, this time, however, almost pure snow-white, the reprecipitation and solution having served to purify the precipitate. The snow-white mass was now collected on a filter and dried, becoming then a fine snow-white powder. A portion of this powder was dissolved in a small amount of water, the solution added to sterilized milk in a test tube, placed at 35° C., and curdling of the milk occurred in one hour. In order to determine whether the ferment thus obtained contained the tryptic ferment in any considerable quantity, a little of the water solution was added to a test tube of solidified gelatine in order to determine if a peptonization of the gelatine took place. No appreciable solution of the gelatine occurred; from which the conclusion was drawn that the precipitate did not contain the tryptic ferment in any considerable quantity.

EXPERIMENT 4.

Organism No. 8 was inoculated into a flask of sterilized milk, and allowed to grow for four weeks. After adding to the culture a little water, it was filtered through porcelain and the rennet was isolated as in the previous experiment, by common salt. After the separation of the snow-white precipitate, which appeared when the salt was added, the filtrate was allowed to drop into strong alcohol. This produced a second precipitate, composed partly of salt and partly of a white flocculent mass. The latter was separated so far as possible from the salt precipitate, and was collected on a filter and dried. In this way a second white powder was obtained, which was supposed to contain the tryptic ferment. Upon adding a little of the solution of this last ferment to milk, a second portion to a little fibrin, it was found that no appreciable digestion either of the casein or of the fibrin took place. The sterilized milk was found after a long time to become curdled, but coagulation took place very slowly. This water solution, however, did possess the power of peptonizing gelatine, since it readily liquefies solidified gelatine in a few hours. This indicates that it contains a certain quantity of tryptic ferment, and consequently shows that the use of salt to precipitate the rennet and then alcohol to precipitate the tryptic ferment is a means of at least partially separating the two ferments.

It is a little surprising to find that, although the organisms when growing in milk do have the power of digesting milk casein, the tryptic ferment obtained as above described, does not possess this power. My only explanation at present is that the porcelain cylinder holds back much of the ferment mechanically, and the filtrate contains only a fraction of the amount originally present. It has been recently pointed out by Duclaux (Ann. de l'Inst. Pasteur, 1892, p. 854) that such an effect is produced by porcelain filters. If the porcelain filter has this effect, it would apply equally well to the rennet ferment. Indeed some experiments seem to point to the conclusion. For example, organism No. 6, as shown, usually gave rennet in its solution, but in some experiments no traces of rennet would be found in the porcelain filtrate, although the culture had been carried on as usual. Seemingly the porcelain cylinder had in this case held back all of the rennet ferment.

Similar experiments with organisms Nos. 5, 10, 31, and 32, gave like results. In the case of organisms Nos. 31 and 32, however, the separation of the two ferments proved to be less satisfactory than in the other cases. The salt precipitation seemed to possess a strong power of peptonizing gelatine, and the alcohol precipitate possessed a strong power of curdling milk. This shows that the method adopted for separation of these two ferments is not satisfactory and does not produce a complete separation. At the same time the method of obtaining the rennet from the solution by means of the salt is far more satisfactory than the method of precipitating it by alcohol, and does, at least in some cases, give a much purer form of the enzyme than is obtained by the simple action of alcohol.

Organisms 6, 9, and 32 were especially interesting for one peculiar feature. These organisms, as will be seen from the description given above, do not possess the property of curdling milk at a high temperature, although doing so at the temperature of the room. All three of them, however, do peptonize the casein, converting it into a somewhat transparent solution of peptonized casein. This occurred in the case of all the organisms when they grow at a temperature of 35° C., as well as at 20° C. The seeming conclusion to be drawn from this is that the organisms in question do not produce the rennet ferment at a temperature of 35° C., but that all of them do produce the tryptic ferment in considerable quantities. It will be seen, however, from the above experiments that this is not a legitimate conclusion, for all three of these organisms are found by experiment to produce rennet in considerable quantity.

EXPERIMENT 5.

For instance, organism 6 is cultivated in the oven at a temperature of 35° C. The milk does not become curdled by the action of the organism, but after two weeks is converted into a partially transparent mass, which plainly indicates a peptonization of the casein. The culture is now filtered through porcelain and the filtrate treated in the manner above described, and there appears as usual the snow-white scum on the surface when the solution has become saturated with salt. This scum, upon being collected, dried, and tested in sterilized milk, is found to contain the rennet ferment, inasmuch as it curdled the milk in a short time. The same result is obtained from experiments with the other two organisms, and we therefore conclude from this that these organisms do produce the rennet ferment under a temperature of 35° C., just as surely as any other of the organisms experimented upon. From experiment 7, described below, it will be seen that the bacillus of hog cholera, which does not curdle milk at any temperature, does produce rennet when growing in milk, thus agreeing with the other organisms studied. We are forced, however, to conclude that the temperature of 35° C. is more favorable for the production of the tryptic ferment, and that this ferment was produced so rapidly at this temperature that it peptonized the casein of the milk before the rennet had accumulated in sufficient quantity to precipitate it in the form of a solid curd. The same organisms growing at a lower temperature do not produce the tryptic ferment so rapidly, and the rennet ferment is produced in sufficient quantities to precipitate the casein before it is peptonized. In order to test this conclusion the following experiments were made:

EXPERIMENT 6.

Organism No. 8 was inoculated into two flasks of sterilized milk. One was placed at 35° C., the other was left in the room at a temperature of about 20° C. After growing four days, equal quantities of each solution were filtered through the porcelain cylinder and treated in the normal way for the precipitation of the rennet. It was found that the culture which had been growing at a temperature of 20° C. gave a considerably larger quantity of rennet than the one growing at 35° C. The rennet obtained from the first culture was also much lighter colored than that obtained from the culture which had been at 35° C. This indicated plainly that the latter culture contained a large quantity of products of tryptic digestion. After separating the rennet from the two cultures, the filtrate was treated with a quantity of alcohol to precipitate the other ferments in solution. The precipitate obtained from 35° C. was larger in amount than that obtained from 20° C. This experiment serving as a test of the conclusion above reached, indicated that the temperature of 35° C. is more favorable for the production of a tryptic ferment, while a temperature of 20° C. is more favorable for the production of the rennet ferment.

The impossibility of obtaining any quantitative tests of the amount of rennet produced by the cultures owing to the impurities present, has rendered any further experimentation in this line impossible. It can only be stated in general that in all of the experiments which were carried on, it was found that, provided the organism would grow at all at a temperature of 20° C. the amount of rennet ferment produced at this temperature was considerably greater than the amount produced at a warmer temperature of 35° C., and all the experiments upon the isolation of rennet were therefore conducted at the lower rather than the higher temperature.

From these experiments it will be seen that the production of rennet does not always make itself evident by a curdling of the milk. Occasionally organisms are found which peptonize milk without curdling it, and one species has been found by the author that at first possessed both the curdling and peptonizing power, but which lost the former after several months' cultivation. The inference from the above results is that rennet is produced in these cases as in others, but that the peptonizing ferment action disguises it. Indeed, one of the organisms from which I have succeeded in isolating rennet was of this class, refusing to curdle milk at all. Unfortunately, the organism was lost before its characteristics were carefully made out, and it does not therefore appear in the above list. One further set of experiments bearing upon this point is to be mentioned here.

Through the kindness of Dr. Moore, of the U. S. Bureau of Animal Industry, I obtained a culture of the hog cholera bacillus. This organism has no power of curdling milk, but under its influence, both at 35° C. and also at a lower temperature, milk is slowly rendered transparent in the same way as described in the experiment above mentioned. This rendering of the milk transparent was attributed by Dr. Moore to the production of an alkaline reaction and not to any peptonizing ferment. Similar effects can be produced by adding N_aOH to milk. The similarity of the action to that in the organisms which have been described above led me to believe that here also there was a production of both a rennet and a tryptic ferment, and the following experiment was made to test the question.

EXPERIMENT 7.

Two flasks of sterilized milk were inoculated with the hog cholera bacillus, one placed at 35° C. and the other at the temperature of the room. The culture placed in the oven failed to curdle, but in two weeks became well digested, or at least it became quite transparent. The culture left in the room was affected the same way only to a less extent. After 18 days one-half of the culture which had been at 35° C. was filtered and treated in the usual manner for the isolation of the rennet ferment. Scarcely any enzyme could be obtained by the use of salt. The very small amount of precipitate which was obtained, however, contained rennet, as was proved by the fact that it curdled milk in about 12 hours. The filtrate from the salt solution was treated with a large amount of strong alcohol to isolate the rest of the enzyme that might be present, and only a very small amount of precipitate was thrown down by the alcohol. The small amount which was obtained was collected and dissolved in water, but further experiment did not show any power of curdling milk nor of peptonizing gelatine. One week later the culture which had been growing at the temperature of the room, having by this time shown considerable tendency to become transparent, was treated in the same way with precisely similar results, only an extremely small amount of either the rennet or the tryptic ferment being obtained. At the same date, after a growth of 25 days, the other half of the first culture was filtered and the precipitate that appeared upon the addition of salt was a little greater than that of the week before, but was still very small in quantity, and showed only very slight power of curdling milk. The whole precipitate from the culture required 10 hours to produce the curdling of 10c.c. of milk. The filtrate from the salt solution was treated with alcohol, and, as before, an extremely small amount of precipitate was thrown down by the alcohol. This precipitate, presumably containing the tryptic ferment, was collected on a filter, dissolved in water, and its properties tested. It was found to possess the peptonizing ferment in a very slight degree, and was also found to have a very slight power of curdling milk. The experiment as above described shows that the hog cholera bacillus does produce both rennet and a tryptic ferment, but that the amount of these two ferments produced is extremely small. At least the amount which passes through the porcelain filter is very small. So small is the amount that it is improbable that the digestion of the curd which appears as a result of the action of this organism can be due to the tryptic-like ferment.

The production of rennet ferment by the bacteria in question has been proved to be a rather slow process. The following experiments will indicate that this is true.

EXPERIMENT 8.

Organism No. 10 was inoculated into two flasks of sterilized milk, one placed in the oven and the other kept at the temperature of the room. After five days one-half of each culture was filtered through porcelain, and the rennet isolated from it in the usual way. A very small quantity of rennet was separated by use of the saturated salt solution. Neither the culture growing in the oven nor that in the room had as yet produced rennet in any considerable quantity. Moreover, the small amount of white scum which was separated from the solution by the addition of salt was found to contain a very small proportion of rennet, inasmuch as it required more than 16 hours to curdle milk by its action. The other half of the same cultures were allowed to grow for six weeks, and at the end of that time again filtered and treated in the usual manner. The amount of rennet produced in this case was much greater than that produced in the earlier test.

EXPERIMENT 9.

Organism No. 8 was in like manner inoculated into flasks of sterilized milk, and after four days' growth one-half of the culture was filtered and treated as usual. An extremely small amount of rennet ferment was produced, such a small amount, indeed, that milk did not curdle in 24 hours by its action. The culture was allowed to grow for five weeks and again treated in the same manner, and a large quantity of rennet was obtained, very strong in its curdling power, precipitating the casein in sterilized milk in one and one-half hours.

In the same way the other organisms studied were found to produce rennet ferment quite slowly, and it was soon found necessary in the experiments to carry on the cultivation of the organisms for something like two weeks in order to be sure of obtaining a sufficient quantity of rennet in the solution to isolate it satisfactorily. This is perhaps a little surprising, inasmuch as the curdling of milk under the influence of the bacteria growth is quite a rapid process and usually occurs inside of a couple of days. It furnishes another indication that much of the enzyme is retained by the porcelain filter.

The rennet that has been isolated from the organisms is certainly not pure. It requires from an hour to eight or ten hours, and sometimes longer, for a considerable quantity of its solution to produce the precipitation of the casein from 10c.c. of milk, and pure rennet, isolated from the stomach of mammals, acts in a very much shorter time than this. The chemical reactions of the rennet obtained in my experiments do not agree in all respects with the chemical reactions of pure rennet as described by Hammersten. The difficulty of obtaining this rennet in any considerable quantity has made it impossible, however, at present, to experiment with the enzyme sufficiently to obtain it in any purer condition than that described in the above experiment.

In all of the experiments above described, the rennet was produced by culture of the organism in milk. It is not necessary, however, to use milk for a culture, since the various organisms will produce these ferments when grown in simple bouillon solutions, although not so readily or in such quantity as when grown in milk. The following three experiments show this fact.

EXPERIMENT 10.

Organism No. 5 was inoculated into a solution of beef peptone bouillon and allowed to grow for two weeks. It was then filtered and treated in the usual manner for the isolation of the rennet. A small quantity of rennet was obtained in this way, which, when dried and dissolved in water, was found to possess the power of precipitating the casein 10c.c. of milk in a little more than an hour.

EXPERIMENT 11.

Organism No. 10 was inoculated into a solution of beef peptone bouillon plus three per cent. milk sugar. It was allowed to grow in the room for over two months. At the end of that time it was filtered and treated as usual for the separation of rennet. A small quantity of rennet only was obtained from the solution, and the rennet that was obtained was found to possess the curdling power in rather less degree than was possessed by the rennet isolated from the same organism when grown in milk.

EXPERIMENT 12.

Organism No. 8 was in like manner cultivated in bouillon for one week. It was found that a smaller quantity of rennet could be obtained from the solution than was obtained from the culture of the same organism when grown in milk for one day. The rennet isolated had very feeble curdling power, requiring nearly 24 hours to precipitate the casein of milk.

It would seem from these experiments that at least in regard to these three organisms, the production of rennet takes place more readily when the organisms grow in milk than when they grow in bouillon solution.

The following experiments were performed to determine the temperature at which the rennet was destroyed by heat. The difficulty of getting a large quantity of rennet has made it impossible to conduct these experiments as yet in as thorough a manner as desirable, but the two experiments described indicate at all events that the relation of this rennet to high temperatures is essentially the same as that of other enzymes.

EXPERIMENT 13.

A quantity of rennet was isolated from a milk culture of No. 8, and was then dissolved in water and an equal quantity of it added to four tubes containing about 5c.c. of sterilized milk. No. 1 was heated to a temperature of 70° C., No. 2 to a temperature of 74° C., No. 3 to a temperature of 75° C., and No. 4 served as a control experiment. All the test tubes were then placed in an oven at a temperature of 35° C. The control was found to curdle in two hours. None of the other tubes were curdled in 24 hours, but all of them became curdled in 48 hours. Whether this was due to the action of the rennet or to growth of accidental organisms was not determined by the experiment.

EXPERIMENT 14.

Organism No. 10 was cultivated in milk and the rennet isolated in the usual manner. The rennet was dissolved in water and an equal quantity of it added to each of 6 test tubes of sterilized milk. No. 1 served as the control, No. 2 was heated to 60° C. for 5 minutes, No. 3 to 65° C. for 5 minutes, No. 4 to 70° C. for 5 minutes, No. 5 to 75° C. for 5 minutes, and No. 6 to 80° C. for 5 minutes. All were then placed at a temperature of 35° C. No. 1, the control, was found to curdle in five and one-half hours; No. 2 (60°) curdled in 10 hours; No. 3 (65°) in 26 hours; No. 4 (70°) in 44 hours; No. 5 and No. 6 did not curdle at all.

From these experiments it is plain that the bacteria rennet, like other enzymes, is destroyed by a temperature between 70° C. and 80° C., but the exact temperature is somewhat variable, and indeed it would seem that the heat acts gradually in destroying the rennet.

SUMMARY.

(1) Many species of bacteria that have the power of liquefying gelatine, produce, as a result of their growth in milk, a certain quantity of an enzyme which, so far as can be at present determined, has all of the essential characteristics of rennet.

(2) This rennet can be isolated from bacteria cultures by filtering the cultures through a porcelain cylinder and then treating the filtrate with alcohol. A better method, which gives the rennet in a purer condition, though by no means pure, is to precipitate it from its solution by an excess of salt instead of alcohol.

(3) It has been found possible to isolate this rennet from milk in the case of all species of bacteria thus far studied which curdle the milk without rendering it acid.

(4) Different species of bacteria differ very much in the amount of rennet which they produce and the rapidity with which they produce it.

(5) Several species of bacteria have been found to produce rennet in considerable quantity, even where they are not capable of curdling the milk. The explanation of the fact is that the production of a tryptic ferment obscures the production of the rennet ferment in these cases, and the casein becomes peptonized before it can be precipitated by the more slowly forming rennet.

(6) The organisms experimented upon seemed in every case to produce a larger amount of rennet when growing at a moderately low temperature than when growing at a temperature of 35° C.

(7) The rennet, isolated in this way, has all of the general reactions of dairy rennet, and is subject to destruction by high temperatures in a similar manner.

FEEDING EXPERIMENTS WITH MILCH COWS ON SOILING CROPS.

BY C. S PHELPS.

During the summers of 1891 and 1892 the Station has carried on a series of feeding tests with various fodder crops, the soiling system having been followed. The animals were fed in the stables, but had "the run" of a small yard several hours each day. The green fodders were hauled, as a rule, every second day, and a two days' supply weighed at once and left in baskets or separate piles till needed. During all of the tests there was fed a standard grain ration, mixed, in most cases, with cut hay or oat straw. The object of the experiments was to study the value of various green fodders for milk and butter production, and the effect of the rations on the composition of the milk, with especial reference to the quantity of fat produced. In 1891 the fats only were determined, and in 1892 both the fats and solids. The determinations were made at each milking, night and morning. The total amount of butter fat was estimated by multiplying the weight of milk from each milking by its percentage of fat and adding the results for the four or seven days which made up the test.

THE EXPERIMENTS.

During the seasons of 1891 and 1892 green fodder crops were fed from about June 1st till November 1st, and the feeding tests were carried on in 1891 from June 8th till September 22d, and in 1892 from May 29th till August 15th. The amount of green fodder fed varied from 50 to 75 pounds, according to the moisture in the crop. The quantities were regulated more or less by the appetites of the animals. The grain ration remained constant for both seasons and was fed with a small quantity of cut hay or oat straw.

Four animals were used each season, and in 1891 consisted of the following: Cows No. 2 and 5 were grade Jerseys about seven years old, and had calved during the first week of November, 1890. Their weights at the beginning of the tests were 770 and 830 pounds respectively. Cow No. 1 was a high grade Jersey, six or seven years old, that had calved February 11th, 1891, and weighed 740 pounds, and cow No. 3, a Guernsey and high grade Jersey cross, that had calved February 5th, 1891, and weighed 950 pounds. The same animals were used in the experiments of 1892, with the exception that the grade Jersey No. 5, was replaced by another. No. 5 calved about October 1st, 1891, and weighed June 18th, 1892, 850 pounds. Cow No. 2 calved December, 1891, cow No. 3, February 12th, and cow No. 1, April 3d, 1892. It will be observed that two of the cows were well along in their periods of lactation, having given milk from six to eight months when the tests began, while the other two were two to four months past calving.

The tests in 1891 were each four days in length and in 1892 seven days, and whenever practicable two or more tests were made from the same fodder. In all cases three or four days were allowed to accustom the animals to a new feed before the tests were begun.

COMPOSITION OF THE FODDERS.

Analyses of Green Fodders Grown by Station.

Year.	KIND OF CROP.	Water.	Protein.	Fat.	Nit.-Free Ext.	Fiber.	Ash.	Potential Energy.
		%	%	%	%	%	%	Calor's per lb.
1891	Wheat,	69.9	3.7	1.0	14.8	9.0	1.6	550
1892	Wheat,	76.2	2.6	.9	12.5	6.3	1.5	440
1892	Wheat.	74.2	2.2	1.0	12.9	8.1	1.6	475
1891	Oats and peas,	82.9	3.0	.6	7.4	4.7	1.4	305
1892	Oats and peas,	83.8	3.5	.7	6.2	4.3	1.5	290
1892	Oats and peas,	84.6	3.5	.8	6.0	3.7	1.4	280
1891	Oats and vetch,	75.4	3.6	.7	11.8	6.5	2.0	440
1891	Red clover rowen,	70.2	6.0	1.4	13.6	6.7	2.1	550
1891	Timothy and clover rowen,	81.3	3.7	.9	8.0	4.3	1.8	335
1892	Red clover rowen,	75.4	4.7	.8	11.1	6.0	2.0	440
1892	Scarlet clover,	79.5	3.1	.8	8.5	6.3	1.8	365
1891	Hungarian,	72.8	2.5	.8	14.1	7.7	2.1	485
1891	Hungarian,	72.7	3.3	.8	12.6	7.9	2.7	475
1892	Hungarian,	71.5	3.1	.9	13.3	9.1	2.1	515
1892	Hungarian,	72.4	1.9	.9	14.0	8.6	2.2	500
1891	Cow peas,	83.6	3.2	.4	7.7	3.3	1.8	280
1892	Cow peas,	88.3	2.5	.4	4.1	3.2	1.5	200
1891	Barley and peas,	84.1	3.0	.6	6.1	4.3	1.9	275

The table which precedes gives the composition of the green fodders used. Each fodder was sampled during the time of feeding, and the results of the analyses are given, calculated to water content at the time of sampling.

THE RATIONS FED.

During most of the trials 60 pounds of green fodder was used per cow per day. The grain remained constant, and consisted of three pounds of corn meal and one pound of new process linseed meal per day, and the dry hay or oat straw varied in amount from three pounds down to nothing, being lessened whenever the animals were inclined to refuse it. Owing to the small number of digestion experiments on green fodders from which data might be had, it was thought best to assume uniform digestion coefficients for all of the fodders. These are essentially the same as Armsby* gives for red clover beginning to blossom, and were as follows: For protein, 75 per cent.; digestible fat, 60 per cent.; nitrogen-free extract, 75 per cent.; and fiber, 50 per cent. The estimates of energy are made as explained in the Report of this Station for 1890, pages 174–181.

From the table (38) of rations, given on the following page, it will be seen that the amount of total digestible nutrients in the fodders varied widely. It will also be noticed that the proportions of protein were largest wherever clover, vetch, peas or other plants of this class entered largely into the rations. By comparison with the standard ration given at the bottom of the table, it will be seen that rations VII., IX., and XIV., which gave the most striking results in the feeding tests, were much narrower, that is, contained a much larger proportion of protein, than that called for by the German standard of Wolff. Recent German experiments on milch cows have shown that better results are obtained from the use of considerably larger quantities of protein than the German standards have hitherto called for.

The difficulties with these experiments as accurate tests are numerous, but are too apparent to require detailed discussion. The small number of cows used, the shortness of the feeding periods, and the variations in the quantities of nutritive materials in the different rations, all interfere with the reliability of the inferences to be drawn, and the results are simply presented for what they are worth.

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* Manual of Cattle-feeding.

TABLE 38.—*Amounts of Digestible Nutrients and Calories of Potential Energy in the Rations.*

No. of Ration.	KINDS OF FEED.	Weight as Fed.	Total Dry Matter.	DIGESTIBLE NUTRIENTS.				
				Protein.	Fat.	Carbo-hydrates.	Potential Energy.	Nutritive Ratio.
1891.		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	
I.	Wheat fodder, - -	42	12.64	1.16	.26	6.53		
	Hay, - - - -	5	4.29	.21	.07	2.07		
	Corn meal, - - -	3	2.60	.22	.10	1.96		
	New Process linseed meal,	1	.90	.29	.03	.37		
	Total, - - -		**20.43**	**1.88**	**.46**	**10.93**	**25770**	**1:5.9**
II.	Timothy and clover, -	50	14.45	1.31	.29	7.50		
	Grass and hay same as I.,		7.79	.72	.20	4.40		
	Total, - - -		**22.24**	**2.03**	**.49**	**11.90**	**27980**	**1:6.5**
III.	Oats and peas, - -	50	8.53	1.11	.19	3.94		
	Grain same as I., hay 3 lbs.		6.07	.63	.17	3.57		
	Total, - - -		**14.60**	**1.74**	**.36**	**7.51**	**18720**	**1:4.8**
IV.	Oats and peas, - -	60	10.23	1.33	.23	4.73		
	Grain & hay same as III.,		6.07	.63	.17	3.57		
	Total, - - -		**16.30**	**1.96**	**.40**	**8.30**	**20770**	**1:4.7**
V.	Oats and vetch, -	60	14.75	1.63	.26	6.71		
	Grain & hay same as III.,		6.07	.63	.17	3.57		
	Total, - - -		**20,82**	**2.26**	**.43**	**10.28**	**25140**	**1:5.0**
VI.	Hungarian, - - -	60	16.33	1.15	.28	8.68		
	Grain & hay same as III.,		6.07	.63	.17	3.57		
	Total, - - -		**22.40**	**1.78**	**.45**	**12.25**	**27990**	**1:7.5**
VII.	Clover rowen, - -	60	17.89	2.69	.51	8.13		
	Hay, - - - -	2	1.71	.08	.03	.83		
	Grain same as I., - -		3.50	.51	.13	2.33		
	Total, - - -		**23.10**	**3,28**	**.67**	**11.29**	**29930**	**1:4.0**
VIII.	Hungarian, - - -	60	16.36	1.49	.28	8.05		
	Grain & hay same as VII.,		5.21	.59	.16	3.16		
	Total, - - -		**21.57**	**2.08**	**.44**	**11.21**	**26530**	**1:5.9**
IX.	Clover and timothy rowen,	60	11.20	1.68	.31	4.91		
	Grain & hay same as VII.,		5.21	.59	.16	3.16		
	Total, - - -		**16.41**	**2,27**	**.47**	**8.07**	**21220**	**1:4.1**
X.	Cow peas, - - -	60	10.69	1.25	.17	5.05		
	Grain & hay same as VII.,		5.21	.59	.16	3.16		
	Total, - - -		**15.90**	**1.84**	**.33**	**8.21**	**20090**	**1:4.9**
1892.								
XI.	Wheat fodder, - -	60	14.87	1.08	.34	7.59		
	Oat straw, - - -	2	1.81	.03	.01	.81		
	Corn meal, - - -	3	2.51	.22	.08	1.89		
	New Process linseed meal,	1	.88	.30	.03	.34		
	Total, - - -		**20.07**	**1.63**	**.46**	**10.63**	**24750**	**1:7.2**
XII.	Oats and peas, - -	70	11.06	1.85	.32	4.60		
	Grain & straw same as XI.,		5.20	.55	.12	3.04		
	Total, - - -		**16.26**	**2.40**	**.44**	**7.64**	**20530**	**1:3.6**
XIII.	Hungarian, - - -	70	19.95	1.62	.38	10.15		
	Grain same as XI., -		3.39	.52	.11	2.23		
	Total, - - -		**23,34**	**2.14**	**.49**	**12.38**	**29080**	**1:6.4**
XIV.	Clover (mixed), - -	60	12.90	1.57	.27	6.00		
	Grain same as XI., -		3.39	.52	.11	2.23		
	Total, - - -		**16.29**	**2.09**	**.38**	**8.23**	**20600**	**1:4.4**
XV.	Hungarian, - - -	70	19.37	1.00	.37	10.38		
	Grain same as XI., -		3.39	.52	.11	2.23		
	Total, - - -		**22.76**	**1.52**	**.48**	**12.61**	**28310**	**1:9.1**
	German standard for 800 lb. cow, - -		19.20	2.00	.32	10.00	23670	1:5.4

THE RESULTS OF THE EXPERIMENTS.

Table 39, which follows, gives the pounds of milk, the pounds of fat, and the average percentages of fat for the four cows, in periods of four days for 1891, and seven days for 1892. The total solids produced in seven days and the average percentage of solids are also given in the results for 1892. It must be borne in mind that as cows advance in their periods of lactation there is a natural shrinkage in the milk flow, and a slow, but more or less gradual rise in the percentage of fat and solids contained in the milk. For this reason only tests that are quite near each other in point of time are comparable.

TABLE 39.

Average Results of Experiments with Four Cows.

No. of Period.	No. of Ration.	KINDS OF FEED.	Milk.	Fat.		Solids.		Butter by Churning.	Milk required to make 1 lb. Butter.
		Periods of 4 days each, 1891.	Lbs.	Lbs.	%	Lbs.	%	Lbs.	Lbs.
1	I.	Wheat, - - - -	327	16.1	5.0	—	—	14.4	23
2	II.	Timothy and clover, -	284	14.4	5.1	—	—	14.0	20
3	II.	Timothy and clover, -	267	13.6	5.1	—	—	13.7	19
4	III.	Oats and peas, - -	269	13.3	4.9	—	—	13.9	19
5	IV.	Oats and peas, - -	270	13.4	5.0	—	—	14.2	19
6	IV.	Oats and peas, - -	266	12.9	4.9	—	—	13.3	20
7	V.	Oats and vetch, - -	248	11.9	4.8	—	—	12.5	20
8	V.	Oats and vetch, - -	237	11.7	4.9	—	—	12.5	19
9	VI.	Hungarian, - - -	249	12.4	5.0	—	—	13.1	19
10	VII.	Clover rowen, - -	283	15.6	5.5	—	—	16.4	17
11	VII.	Clover rowen, - -	289	14.9	5.2	—	—	16.1	18
12	VII.	Clover rowen, - -	269	13.7	5.1	—	—	14.4	19
13	VIII.	Hungarian, - - -	249	12.6	5.1	—	—	12.7	20
14	IX.	Clover and timothy, -	230	13.4	5.8	—	—	13.3	17
15	IX.	Clover and timothy, -	236	12.7	5.4	—	—	13.1	18
16	X.	Cow peas, - - -	205	11.0	5.4	—	—	10.9	19
17	X.	Cow peas, - - -	214	11.4	5.3	—	—	11.0	19
18	X.	Cow peas, - - -	212	11.3	5.3	—	—	11.8	18
		Periods of 7 days each, 1892.							
19	XI.	Wheat, - - - -	553	24.7	4.5	74.3	13.5	26.4	21
20	XI.	Wheat, - - - -	490	22.6	4.7	68.6	14.1	24.8	20
21	XII.	Oats and peas, - -	391	18.4	4.8	54.0	14.0	18.1	22
22	XII.	Oats and peas, - -	379	17.5	4.7	51.0	13.6	18.6	21
23	XII.	Oats and peas, - -	371	17.2	4.8	49.6	13.8	19.8	19
24	XIII.	Hungarian, - - -	368	18.1	4.9	50.3	13.8	19.8	19
25	XIV.	Clover, - - - -	363	18.5	5.2	51.2	14.1	20.5	18
26	XV.	Hungarian, - - -	342	16.5	4.9	47.7	13.9	18.9	18

TABLE 40.

Total Pounds of Milk, Butter, Fat, and Average Percentage of Fat, in Periods of 4 Days (1891), and 7 Days (1892).

No. of Period.	No. of Ration.	End of Period.	KINDS OF FEED.	Cow No 1.			Cow No. 3.			Cow No. 2.			Cow No. 5.		
				Milk.	Fat.	Fat.	Milk.	Fat.	Fat.	Milk.	Fat.	Fat.	Milk.	Fat.	Fat.
		1891.	*Periods of 4 days each, 1891.*	Lbs.	Lbs.	%	Lbs.	Lbs.	%	Lbs.	Lbs.	%	Lbs.	Lbs.	%
1	I.	June 13,	Wheat,	94.4	4.2	4.45	97.1	5.0	5.15	64.8	3.7	5.71	70.4	3.2	4.55
2	II.	19,	Grass,	80.2	3.9	4.86	83.5	4.3	5.15	55.6	3.2	5.76	64.5	3.0	4.65
3	II.	24,	Grass,	75.4	3.8	5.04	78.7	3.9	4.96	52.6	3.0	5.70	60.1	2.9	4.83
4	III.	July 2,	Oats and Peas,	76.8	3.7	4.82	80.0	3.9	4.88	52.2	2.9	5.56	60.3	2.8	4.64
5	IV.	10,	Oats and Peas,	76.8	3.7	4.82	78.2	3.9	4.99	54.9	3.1	5.65	60.1	2.7	4.49
6	IV.	17,	Oats and Peas,	79.3	3.7	4.67	76.5	3.5	4.58	52.4	3.0	5.73	57.4	2.7	4.70
7	V.	24,	Oats and Vetch,	71.3	3.2	4.49	75.4	3.4	4.51	48.0	2.8	5.83	53.6	2.5	4.66
8	V.	28,	Oats and Vetch,	65.0	3.1	4.77	73.4	3.4	4.63	45.7	2.7	5.91	52.9	2.5	4.73
9	VI.	Aug. 3,	Hungarian,	70.5	3.3	4.68	73.6	3.6	4.89	49.8	2.9	5.82	55.1	2.6	4.72
10	VII.	10,	Clover rowen,	79.8	4.2	5.26	84.6	4.5	5.32	54.2	3.6	6.64	64.1	3.3	5.15
11	VII.	14,	Clover rowen,	77.4	3.8	4.91	89.5	4.4	4.92	55.5	3.4	6.13	66.8	3.3	4.94
12	VII.	18,	Clover rowen,	72.2	3.7	5.12	82.8	3.9	4.71	52.8	3.1	5.87	61.4	3.0	4.89
13	VIII.	27,	Hungarian,	64.9	3.2	4.93	79.1	3.6	4.55	49.7	3.0	6.04	55.3	2.8	5.06
14	IX.	Sept. 2,	Clover and Timothy,	62.6	3.5	5.59	76.7	4.2	5.48	44.1	2.9	6.58	46.6	2.8	6.01
15	IX.	6,	Clover and Timothy,	65.3	3.4	5.21	81.2	4.1	5.05	43.7	2.7	6.18	45.8	2.5	5.46
16	X.	14,	Cow Peas,	59.4	3.0	5.05	67.0	3.4	5.08	37.4	2.4	6.42	40.7	2.2	5.41
17	X.	18,	Cow Peas,	62.0	3.1	5.00	70.7	3.6	5.09	39.1	2.5	6.39	41.7	2.2	5.28
18	X.	22,	Cow Peas,	59.6	3.0	5.03	73.0	3.6	4.93	37.9	2.4	6.33	41.7	2.3	5.52
		1892.	*Periods of 7 days each, 1892.*												
19	XI.	June 5,	Wheat,	170.9	6.7	3.86	155.1	7.2	4.66	125.4	6.5	5.18	101.2	4.3	4.28
20	XI.	12,	Wheat,	142.8	5.8	4.04	144.7	6.6	4.55	111.6	6.0	5.41	90.6	4.2	4.58
21	XII.	July 3,	Oats and Peas,	124.5	5.3	4.24	119.3	5.4	4.53	96.6	5.3	5.45	50.3	2.5	4.91
22	XII.	10,	Oats and Peas,	126.1	5.2	4.15	118.5	5.3	4.47	91.0	5.0	5.45	43.6	2.0	4.66
23	XII.	17,	Oats and Peas,	121.0	5.5	4.54	122.4	5.5	4.45	89.7	4.5	5.54	38.3	1.8	4.67
24	XIII.	27,	Hungarian,	117.2	5.4	4.61	123.7	5.8	4.72	89.8	5.1	5.67	36.9	1.7	4.66
25	XIV.	Aug. 7,	Clover,	118.2	5.7	4.79	129.7	6.1	4.72	84.2	5.1	6.08	30.8	1.6	5.19
26	XV.	15,	Hungarian,	116.9	5.3	4.52	120.4	5.4	4.48	81.2	4.7	5.78	23.5	1.2	4.88

In table 40, on the preceding page, the results are given somewhat in detail for each of the four cows for four-day tests in 1891, and for seven-day tests in 1892.

The tests of especial interest are those with clover and with Hungarian grass Nos. 9–15. In the tests with clover in 1891 it will be noticed that there was, in the case of each cow, considerable increase in the milk flow, in the total fat, and in the percentage of fat in the milk over that of the Hungarian test just preceding. This increase was most marked during the first clover test.

The Hungarian tests following the three clover tests showed, in the case of each cow, a falling off in the total fat, and in the case of cows 1 and 3, a slight decrease in the percentage of fat. During the tests with clover and timothy rowen (Nos. 14 and 15), there was an increase in the percentage of fat varying from fifty-five hundredths to a little less than one per cent. This increase in the percentage of fat was followed, in the case of cows 1 and 3, by a gradual falling off during the succeeding cow pea test. Cows 2 and 5 gave a decided increase in the percentage of fat during these clover tests, but showed only a slight decrease in the percentage during the succeeding cow pea test. This circumstance may perhaps be accounted for by the fact that cows 2 and 5 were then well advanced in their periods of lactation. At such a time the percentage of fat becomes naturally high and seems to remain high without very much regard to feed.

During the experiments of 1892 similar tests were made with clover rowen and with Hungarian. From the tables of composition and the rations fed it will be seen that the clover feed in 1892 was not as rich in protein as in 1891. With all but one of the cows there was an increase in the percentage of fat when clover was fed, over that obtained during the Hungarian test just before, and with each cow a marked falling off in milk flow and percentage of fat when the cows were again given Hungarian. It is of interest to note, in connection with the more marked falling off during the second Hungarian test, that the fodder was much poorer in protein, and hence the ration was much wider than the one used just before the clover test.

SUMMARY.

The best results on quantity and quality of the products were obtained where rations with relatively large amounts of protein were fed. The experiments seem to indicate that rations containing a larger proportion of digestible protein than that called for by the commonly accepted standards are to be preferred. Large, nitrogeneous rations are especially important early in the period of lactation, when the productive capacity of the cow is most heavily taxed. The quantity and quality of the products may be improved by the use of foods rich in protein, and the manure is more valuable than where starchy foods are fed.

In these experiments, when clover was fed the amounts of milk and butter were considerably increased, and the percentages of fat were higher than during the Hungarian tests just before and after those with clover. The average product from four cows during the first series of clover tests (Aug. 10, 14, and 18,) of 1891, was 281 pounds of milk and 15.6 pounds of butter, and the average percentage of fat was 5.3 per cent.; while for the Hungarian tests (Aug. 3 and 27,) the average quantity of milk was 249 pounds, and of butter 12.9 pounds, and the average percentage of fat 5.0 per cent.

A STUDY OF ACTUAL DIETARIES.

BY CHARLES D. WOODS.

In the last report of this Station* there was given an account of two dietaries which had been studied by the Station. One was the dietary of a boarding house, the other that of a chemist's family. Since then the Station has made a study of six other dietaries, which are reported herewith in detail. The investigation was made in connection with the United States Department of Labor. The first three reported upon were carried out by Mr. H. M. Smith, at that time Assistant Chemist to the Station; the last three by Dr. H. B. Gibson.

The six dietaries studied were as follows:

1. Dietary of a jeweler's family.
2. Dietary of a blacksmith's family.
3. Dietary of a machinist's family.
4. Dietary of a mason's family.
5. Dietary of a carpenter's family.
6. Dietary of a carpenter's family.

The general plan of the investigation included an account of all food materials of nutritive value in the house at the beginning, that purchased during, and that which remained at the end of the experiment. In addition, all the kitchen and table wastes were collected, weighed and analyzed. The amounts of different food materials on hand at the beginning and received during the experiment were added; from this sum the amounts remaining at the end were subtracted. This gave the amount of each material actually used. From the amount thus obtained and the composition of each material, as shown by analysis, the amounts of the nutritive ingredients were estimated. From these were subtracted the amounts of nutrients in the waste, and thus the amounts of nutrients actually eaten were learned.

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*Report of this Station, 1891, pp. 90-106.

An account of the meals taken by the different members of the family, and by visitors, was kept. In this way occasional absences from home or the presence of visitors did not materially affect the experiment. The number of meals for one man, to which the actual meals taken were equivalent, was found, as in the earlier work by Prof. Atwater*. The equivalents are somewhat arbitrary, but are based upon the best data to be obtained. They are as follows :

Estimated Relative Quantities of Potential Energy in Nutriments Required by Persons of Different Classes.

Man at moderate work,	10
Woman at moderate work,	8
Child, 15 to 6 years old,	7
Child, 6 to 2 years old,	5
Child, under 2 years old,	2½

EXPLANATION OF TABLES.

The statistics of the family are concisely given just before the first table of each dietary.

The first table of each dietary (tables 41, 44, 47, 50, 53, and 56) shows the actual amount of food and of nutrients in the food used during the dietary. The weights of the food materials are as they were purchased and used; that is, they include bone and other refuse, except where specified.

The first three columns in the table contain the percentages of protein fat and carbohydrates used in computing the amounts of those nutrients in the different food materials. In all cases where the composition was not fairly well known from previous analyses, specimens of the food materials actually used in the dietary, or specimens as nearly identical as possible, were analyzed. The cases in which special analyses were made in connection with these dietaries are indicated in the table by placing the letter *a* after the name of the material.

The weight of the water-free table and kitchen wastes, and their composition, are given in the last line of the table Exactly what is included in these wastes is explained in the foot note on page 97 of the Report of this Station for 1891.

The second table of each dietary (tables 42, 45, 48, 51, 54, and 57) gives the summary of the food materials and nutrients used in the dietary, the quantities estimated per man per day, and the percentages of food materials of different classes, and of nutrients furnished by each class. The quantities per man per day were found by dividing the weights of the different food materials and nutrients used in the dietary by the number of days for one man, to which the total meals taken were equivalent.

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*See especially 17th Annual Report of the Massachusetts Bureau of Statistics of Labor, pp. 239-329.

The third (last) table in each dietary (tables 43, 46, 49, 52, 55, and 58) gives the nutrients and potential energy in food purchased, in table and kitchen wastes, and in portion actually eaten. The estimates of animal and vegetable nutrients in the waste are computed as below described, and those of potential energy (fuel-value of nutritive ingredients) as explained in an earlier Report.*

It was not practicable in the collection of the wastes to distinguish between that which came from animal and that from vegetable food. It is, however, possible to estimate with more or less of accuracy how much of the nutritive materials came from the animal and how much from the vegetable foods. As there were practically no carbohydrates in any of the animal foods except milk and cheese, and but little in these, we shall not greatly err in assuming that all the waste carbohydrates came from the vegetable foods. It will also be fairly accurate to assume that the proportions of protein and fat in the vegetable portion of the waste were the same as in the whole vegetable food. Taking the percentages of the weights of the carbohydrates in the total waste as the measure of the protein and fats in the vegetable wastes the actual weights of protein and fat in the latter are readily calculated. Subtracting these weights of vegetable protein and fat from the total weight of these ingredients in the waste, the remainders give the amounts of animal protein and fats in the whole waste.

Table 59 summarizes the results of the eight dietary studies which have been made by the Station.

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*Report of this Station, 1890, p. 174.

DIETARY OF A JEWELER'S FAMILY.

The study began Sept. 1, 1891, and continued 30 days.
The family was as follows:—
Man, 70 years old, at very light work.
Man (chemist), 23 years old, moderate exercise.
Woman, 60 years old (assumed = .8 of one man).
Woman, 25 years old, 11 days (assumed as .8 of one man).
The meals taken were equivalent to 285 meals, or 95 days for one man.

TABLE 41.

Food Materials and Table and Kitchen Wastes in Dietary of a Jeweler's Family During Thirty Days.

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
					Nutrients.		
	Protein.	Fat.	Carbohydrates.	Total Food Materials	Protein.	Fat.	Carbohydrates.
ANIMAL FOODS.							
Beef.	%	%	%	Grams.*	Grams.	Grams.	Grams
Shoulder, - - -	19.5	15.6	—	2,297	448	358	—
Sirloin, - - - -	18.5	20.5	—	2,159	400	443	—
Shoulder clod, - -	19.5	15.6	—	928	181	145	—
Suet, - - -	0.9	94.6	—	322	3	305	—
Canned, corned, -	26.7	17.1	—	2,193	586	375	—
Total, - - -				7,899	1,618	1,626	—
Mutton.							
Fore quarter, - -	17.0	29.9	—	701	119	210	—
Total, - - -				701	119	210	—
Lamb.							
Leg, - - - -	18.9	15.3	—	978	185	150	—
Fore quarter, - -	18.1	25.8	—	3,116	564	804	—
Total, - - -				4,094	749	954	—
Pork.							
Ham, salted, smoked,	16.7	39.1	—	320	53	125	—
Pork, salted, - -	0.9	82.8	—	448	4	371	—
Lard, - - - -	—	90.0	—	500	—	450	—
Total, - - -				1,268	57	946	—
Total meats, - -				13,962	2,543	3,736	—

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* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 41.—*(Continued.)*

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
					Nutrients.		
	Protein.	Fat.	Carbo-hydrates.	Total Food Materials.	Protein.	Fat.	Carbo-hydrates.
Fish.	%	%	%	Grams.*	Grams.	Grams.	Grams
Mackerel,	18.2	7.1	—	1,007	183	72	—
Cod, salted,	21.4	0.4	—	1,370	293	5	—
Clams, canned,	10.4	0.8	3.0	1,245	130	10	37
Total,				3,622	606	87	37
Dairy Products, Etc.							
Butter,	—	85.0	—	4,670	—	3,969	—
Milk, *a*	3.4	4.3	4.8	26,137	888	1,124	1,255
Total,				30,807	888	5,093	1,255
Oleomargarine,	—	85.0	—	231	—	196	—
Eggs,	14.9	10.5	—	1,783	266	187	—
Total animal foods,				50,405	4,303	9,299	1,292
VEGETABLE FOODS.							
Wheat flour,	11.0	1.1	74.9	1,343	148	15	1,006
Wheat bread, *a*	10.5	1.5	54.6	8,428	885	126	4,602
Wheat rolls, *a*	8.6	9.4	56.7	12,186	1,048	1,146	6,910
Coffee cake, *a*	9.0	6.8	55.4	2,185	197	149	1,211
Cake, *a*	7.7	14.7	60.3	4,060	313	597	2,448
Cream crackers, *a*	9.3	13.1	69.2	399	37	52	276
Graham crackers,	9.8	13.6	69.7	247	24	34	172
Tapioca and farina,	—	—	97.8	697	—	—	682
Sugar,	—	—	97.8	9,464	—	—	9,256
Molasses,	—	—	73.1	171	—	—	125
Lima beans,	7.1	0.7	22.0	6,004	426	42	1,321
Green corn,	2.8	1.1	14.2	11,202	314	123	1,591
Potatoes,	2.1	0.1	17.9	16,971	356	17	3,038
Sweet potatoes,	1.5	0.4	26.0	11,202	168	45	2,913
Tomatoes,	0.8	0.4	2.5	17,067	137	68	427
Apples, pears & peaches	0.3	0.4	15.9	39,848	120	159	6,336
Muskmellon,	1.4	0.2	20.5	4,043	57	8	829
Bananas,	1.4	1.4	29.8	527	7	7	157
Grapes,	1.6	1.7	21.3	5,833	93	99	1,243
Total,				151,877	4,330	2,687	44,543
Total animal and vegetable foods purchased,				202,282	8,633	11,986	45,835
TABLE & KITCHEN WASTE, *a*	33.3	39.1	20.4	2,258	752	884	461

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* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 42.

Weights and Percentages of Food Materials and of Nutritive Ingredients Used in Dietary of a Jeweler's Family.

KINDS OF FOOD MATERIALS.	WEIGHT IN GRAMS.				WEIGHT IN POUNDS.			
		Nutrients.				Nutrients.		
	Food Materials.	Protein.	Fats.	Carbo-hydrates.	Food Materials.	Protein.	Fats.	Carbo-hydrates.
For Family, 30 Days.	Grams.*	Grams	Grams	Grams	Lbs.	Lbs.	Lbs.	Lbs.
Meats, etc.,	13,962	2,543	3,736	—	30.8	5.7	8.2	—
Fish,	3,622	606	87	37	8.0	1.3	.2	.1
Dairy products, Butter,	4,670	—	3,969	—	10.3	—	8.8	—
Milk,	26,137	888	1,124	1,255	57.6	2.0	2.5	2.8
Total,	30,807	888	5,093	1,255	67.9	2.0	11.3	2.8
Oleomargarine,	231	—	196	—	.5	—	.4	—
Eggs,	1,783	266	187	—	3.9	.6	.4	—
Total animal food,	50,405	4,303	9,299	1,292	111.1	9.6	20.5	2.9
Vegetable food,	151,877	4,330	2,687	44,543	334.8	9.5	5.9	98.2
Total food,	202,282	8,633	11,986	45,835	445.9	19.1	26.4	101.1
Per Man per Day.								
Meats, etc.,	147	27	39	—	.324	.06	.086	—
Fish,	38	6	1	—	.084	.013	.002	—
Dairy products, Butter,	49	—	42	—	.108	—	.093	—
Milk,	275	9	12	13	.606	.020	.027	.029
Total,	324	9	54	13	.714	.020	.120	.029
Oleomargarine,	2	—	2	—	.004	—	.004	—
Eggs,	19	3	2	—	.042	.007	.004	—
Total animal food,	530	45	98	13	1.168	.100	.216	.029
Vegetable food,	1,599	46	28	468	3.525	.101	.062	1.032
Total food,	2,129	91	126	481	4.693	.201	.278	1.061
Percentages of Total Food Purchased.	%	%	%	%				
Meats, etc.,	6.9	29.5	31.2	—	—	—	—	—
Fish,	1.8	7.0	0.7	0.1	—	—	—	—
Dairy products, Butter,	2.3	—	33.1	—	—	—	—	—
Milk,	12.9	10.3	9.4	2.7	—	—	—	—
Total,	15.2	10.3	42.5	2.7	—	—	—	—
Oleomargarine,	0.1	—	1.6	—	—	—	—	—
Eggs,	0.9	3.1	1.6	—	—	—	—	—
Total animal food,	24.9	49.9	77.6	2.8	—	—	—	—
Vegetable food,	75.1	50.1	22.4	97.2	—	—	—	—
Total food,	100.0	100.0	100.0	100.0	—	—	—	—

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 43.

Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of a Jeweler's Family.

		NUTRIENTS.			Potential Energy.
		Protein.	Fats.	Carbo-hydrates.	
For Family, 30 Days.		Grams.	Grams.	Grams.	Calories.
Food purchased,	Animal, - - -	4,303	9,299	1,292	109,420
	Vegetable, - -	4,330	2,687	44,543	225,370
	Total, - - -	8,633	11,986	45,835	334,790
Waste, - -	Animal, - - -	708	857	—	10,875
	Vegetable, - -	44	27	461	2,320
	Total, - - -	752	884	461	13,195
Food actually eaten,	Animal, - - -	3,595	8,442	1,292	98,545
	Vegetable, - -	4,286	2,660	44,082	223,050
	Total, - - -	7,881	11,102	45,374	321,595
Per Man per Day.					
Food purchased,	Animal, - - -	45	98	14	1,150
	Vegetable, - -	46	28	469	2,375
	Total, - - -	91	126	483	3,525
Waste, - -	Animal, - - -	8	9	—	115
	Vegetable, - -	—	—	5	25
	Total, - - -	8	9	5	140
Food actually eaten,	Animal, - - -	38	89	14	1,035
	Vegetable, - -	45	28	464	2,350
	Total, - - -	83	117	478	3,385
Percentages of Total Food Purchased.		%	%	%	%
Food purchased,	Animal, - - -	49.9	77.6	2.8	32.7
	Vegetable, - -	50.1	22.4	97.2	67.3
	Total, - - -	100.0	100.0	100.0	100.0
Waste, - -	Animal, - - -	8.2	7.2	—	3.2
	Vegetable, - -	0.5	0.2	1.0	0.7
	Total, - - -	8.7	7.4	1.0	3.9
Food actually eaten,	Animal, - - -	41.6	70.4	2.8	29.5
	Vegetable, - -	49.7	22.2	96.2	66.6
	Total, - - -	91.3	92.6	99.0	96.1

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* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

DIETARY OF A BLACKSMITH'S FAMILY.

The study began Nov. 11, 1891, and continued 30 days. The family was as follows:—

Man (blacksmith), about 40 years old.
Woman, about 35 (assumed = .8 of one man).
Two boys, 8 to 10 (assumed = 2 × .7 of one man).
The meals taken were equivalent to 288 meals, or 96 days for one man.

TABLE 44.

Food Materials and Table and Kitchen Wastes in the Dietary.

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
					Nutrients.		
	Protein.	Fat.	Carbo-hydrates.	Total Food Materials.	Protein.	Fat.	Carbo-hydrates.
ANIMAL FOODS.							
Beef.	%	%	%	Grams*	Grams	Grams.	Grams.
Round,	18.0	12.3	—	1,361	245	167	—
Ribs,	12.2	27.9	—	2,863	349	799	—
Total,				4,224	594	966	—
Lamb.							
Leg,	15.5	12.6	—	1,814	281	229	—
Total,				1,814	281	229	—
Pork.							
Spare rib,	13.3	23.9	—	5,273	702	1,260	—
Ham, smoked,	14.8	34.6	—	6,690	990	2,315	—
Lard,	—	90.0	—	3,969	—	3,572	—
Pork, salt,	0.9	82.8	—	1,191	11	986	—
Sausage,	13.8	42.8	—	4,621	638	1,978	—
Total,				21,744	2,341	10,111	—
Poultry.							
Chicken,	15.1	1.2	—	2,041	308	24	—
Total,				2,041	308	24	—
Total meats,				29,823	3,524	11,330	—
Fish.							
Cod, salt,	16.0	0.4	—	1,361	218	5	—
Oysters,	6.3	1.6	4.0	907	57	15	36
Total,				2,268	275	20	36

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* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 44.—*(Continued.)*

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
					Nutrients.		
	Protein.	Fat.	Carbo-hydrates.	Total Food Materials.	Protein.	Fat.	Carbo-hydrates.
Dairy Products, Etc.	%	%	%	Grams.*	Grams	Grams.	Grams.
Butter, - - -	—	85.0	—	3,487	—	2,964	—
Milk, *a* - - -	3.6	4.8	3.8	33,962	1,223	1,630	1,291
Milk, skimmed, *a*, -	3.4	3.6	4.3	7,711	262	278	332
Total, - - -				45,160	1,485	4,872	1,623
Eggs, - - -	12.1	10.2	—	387	47	39	—
Total, - - -				387	47	39	—
Mince meat, *a* - -	3.4	5.0	34.1	2,325	79	116	793
Total, - - -				2,325	79	116	793
Total animal food,				79,963	5,410	16,377	2,452
VEGETABLE FOODS.							
Potatoes (15 % refuse),	2.1	0.1	17.9	33,543	704	34	6,005
Turnips (30 % refuse),	1.2	0.2	8.2	873	10	2	72
Onions (10 % refuse),	1.4	0.3	10.1	1,965	28	6	198
Cabbage (15.5 % refuse),	1.5	0.2	4.6	10,948	164	22	504
Beans, dried, - -	23.1	2.0	59.2	907	210	18	537
Apples (25% refuse), -	0.3	0.4	15.9	7,825	23	31	1,244
Cranberries, - -	0.4	0.9	10.9	220	1	2	24
Rice, - - -	7.4	0.4	79.4	340	25	1	270
Maize meal, - -	9.2	3.8	70.6	879	81	33	621
Rye flour, - -	6.7	0.8	78.7	794	53	6	625
Wheat flour, *a* - -	13.7	1.2	72.1	21,546	2,952	259	15,535
Buckwheat, - -	6.9	1.4	76.1	1,247	86	17	949
Oyster crackers, -	11.3	0.8	77.5	794	90	38	615
Sugar, - - -	—	—	97.8	8,826	—	—	8,632
Raisins, - - -	2.7	0.7	71.6	1,219	33	9	873
Total vegetable food,				91,926	4,460	478	36,704
Total animal and vegetable food purchased, - - -				171,889	9,870	16,855	39,156
TABLE AND KITCHEN WASTES, *a* - -	21.7	31.3	41.8	1,492	323	467	623

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 45.

Weights and Percentages of Food Materials and of Nutritive Ingredients Used in Dietary of a Blacksmith's Family.

KINDS OF FOOD MATERIALS.	WEIGHT IN GRAMS.				WEIGHT IN POUNDS.			
	Food Materials.	Nutrients. Protein.	Fats.	Carbo-hydrates.	Food Materials.	Nutrients. Protein.	Fats.	Carbo-hydrates.
For Family, 30 Days.	Grams.*	Grams	Grams	Grams	Lbs.	Lbs.	Lbs.	Lbs.
Meats, etc.,	29,823	3,524	11,330	—	65	8	25	—
Fish,	2,268	275	20	36	5	1	—	—
Dairy products, Butter,	3,487	—	2,964	—	8	—	7	—
Milk,	33,962	1,223	1,630	1,291	75	3	3	3
Milk, skim'd,	7,711	262	278	332	17	—	1	1
Total,	45,160	1,485	4,872	1,623	100	3	11	4
Eggs,	387	47	39	—	1	—	—	—
Mince meat,	2,325	79	116	793	5	—	—	1
Total animal food,	79,963	5,410	16,377	2,452	176	12	36	5
Vegetable food,	91,926	4,460	478	36,704	203	10	1	81
Total animal and vegetable food,	171,889	9,870	16,855	39,156	379	22	37	86
Per Man per Day.								
Meats,	310	36.7	118.0	—	.677	.080	.260	—
Fish,	24	2.9	0.2	0.3	.052	.006	—	.001
Dairy products, Butter,	36	—	30.9	—	.083	—	.068	—
Milk,	354	12.7	17.0	13.4	.781	.028	.038	.029
Milk, skim'd,	80	2.7	2.9	3.5	.177	.006	.006	.008
Total,	470	15.4	50.8	16.9	1.041	.034	.112	.037
Eggs	4	0.5	0.4	—	.010	.001	.001	—
Mince meat,	24	0.8	1.2	8.3	.052	.002	.002	.018
Total animal food,	832	56.3	170.6	25.5	1.832	.123	.375	.056
Vegetable food,	958	46.5	4.9	382.3	2.115	.104	.011	.842
Total food,	1,790	102.8	175.5	407.8	3.947	.227	.386	.898
Percentage of Total Food.	%	%	%	%				
Meats, etc.,	17.4	35.8	67.2	—	—	—	—	—
Fish,	1.3	2.8	.1	—	—	—	—	—
Dairy products, Butter,	2.0	—	17.6	—	—	—	—	—
Milk,	19.7	12.4	9.7	3.2	—	—	—	—
Milk, skim'd,	4.6	2.6	1.7	.8	—	—	—	—
Total,	26.3	15.0	29.0	4.0	—	—	—	—
Eggs,	0.2	0.4	0.2	—	—	—	—	—
Mince meat,	1.3	0.8	0.7	2.0	—	—	—	—
Total animal food,	46.5	54.8	97.2	6.0	—	—	—	—
Vegetable food,	53.5	45.2	2.8	94.0	—	—	—	—
Total food,	100.0	100.0	100.0	100.0	—	—	—	—

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* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 435.6 grams.

TABLE 46.

Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of a Blacksmith's Family.

		Nutrients.			Potential Energy.
		Protein.	Fats.	Carbo-hydrates.	
For Family, 30 Days.		Grams.*	Grams.	Grams.	Calories.
Food purchased,	Animal, - - -	5,410	16,377	2,452	184,540
	Vegetable, - -	4,460	478	36,704	173,215
	Total, - - -	9,870	16,855	39,156	357,755
Waste, - -	Animal, - - -	248	459	—	5,285
	Vegetable, - -	75	8	623	2,935
	Total, - - -	323	467	623	8,220
Food actually eaten,	Animal, - - -	5,162	15,918	2,452	179,255
	Vegetable, - -	4,385	470	36,081	170,280
	Total, - - -	9,547	16,388	38,533	349,535
Per Man per Day.					
Food purchased,	Animal, - - -	56	171	26	1,920
	Vegetable, - -	47	5	382	1,805
	Total, - - -	103	176	408	3,725
Waste, - -	Animal, - - -	2	5	—	55
	Vegetable, - -	1	—	7	30
	Total, - - -	3	5	7	85
Food actually eaten,	Animal, - - -	54	166	26	1,865
	Vegetable, - -	46	5	375	1,775
	Total, - - -	100	171	401	3,640
Percentages of Total Food Purchased.		%	%	%	%
Food purchased,	Animal, - - -	54.8	97.2	6.0	51.5
	Vegetable, - -	45.2	2.8	94.0	48.5
	Total, - - -	100.0	100.0	100.0	100.0
Waste, - -	Animal, - - -	2.5	2.8	—	1.5
	Vegetable, - -	0.8	0.0	1.6	0.8
	Total, - - -	3.3	2.8	1.8	2.3
Food actually eaten,	Animal, - - -	52.3	94.4	6.3	50.0
	Vegetable, - -	44.4	2.8	92.1	47.7
	Total, - - -	96.7	97.2	98.4	97.7

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* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

DIETARY OF A MACHINIST'S FAMILY.

The study began Nov. 16, 1891, and continued 30 days. The family was as follows:—

Man (machinist), 50 years old, at work.

Woman, 45 years old (assumed = .8 of one man).

Three daughters, 14 to 20 years (assumed = 3 × .8 of one man).

The meals taken were equivalent to 383 meals, or 128 days for one man.

TABLE 47.

Food Materials and Table and Kitchen Wastes in Dietary of a Machinist's Family During Thirty Days.

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo-hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo-hydrates.
ANIMAL FOODS.	%	%	%	Grams*	Grams	Grams	Grams
Beef.							
Round (no bone), -	20.5	10.1	—	340	69	34	—
Round, - - -	18.0	12.3	—	1,304	235	160	—
Ribs, - - - -	12.2	27.9	—	2,041	249	569	—
Shoulder clod, - -	17.0	13.7	—	3,062	520	419	—
Total, - - -				6,747	1,073	1,182	—
Veal.							
Chops, - - -	18.3	5.5	—	680	124	37	—
Total, - - -				680	124	37	—
Pork.							
Shoulder, - - -	13.6	28.0	—	2,268	309	635	—
Chops, - - -	13.3	23.9	—	3,685	490	881	—
Ham, smoked, - -	14.8	34.6	—	5,415	802	1,874	—
Salt, fat, - - -	0.9	82.8	—	1,248	11	1,033	—
Pigs' feet, *a* - - -	10.7	10.1	—	3,742	400	378	—
Sausage, - - -	13.8	42.8	—	3,402	470	1,456	—
Bologna, - - -	18.8	15.8	—	2,041	384	323	—
Lard, - - - -	—	90.0	—	3,657	—	3,291	—
Total, - - -				25,458	2,866	9,871	—
Poultry.							
Chicken, - - -	15.1	1.2	—	1,814	274	22	—
Gosling, *a* - - -	13.4	29.8	—	3,629	486	1,082	—
Total, - - -				5,443	760	1,104	—
Total meats, - -				38,328	4,823	12,194	—

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* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 47.—*(Continued.)*

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
					Nutrients.		
	Protein.	Fat.	Carbo-hydrates.	Total Food Materials.	Protein.	Fat.	Carbo-hydrates.
Fish.	%	%	%	Grams*	Grams	Grams	Grams
Haddock, - - -	8.2	0.2	—	1,077	88	2	—
Total fish, - -				1,077	88	2	—
Dairy Products, Etc.							
Butter, - - -	—	85.0	—	5,046	—	4,289	—
Milk, *a* - - -	3.3	5.4	4.0	47,343	1,563	2,557	1,894
Total, - - -				52,389	1,563	6,846	1,894
Eggs, - - - -	12.1	10.2	—	1,286	156	131	—
Total, - - -				1,286	156	131	—
Total animal food, -				93,080	6,630	19,173	1,894
VEGETABLE FOODS.							
Potatoes (15 % refuse), -	2.1	0.1	17.9	29,976	630	30	5,367
Potatoes, sweet, - -	1.5	0.4	26.0	3,374	51	14	877
Onions (10 % refuse), -	1.4	0.3	10.1	995	14	3	101
Cabbage (15 % refuse), -	1.5	0.2	4.6	958	14	2	44
Turnips, - - -	1.2	0.2	8.2	3,572	43	7	293
Beans, dried, - -	23.1	2.0	59.2	227	52	5	134
Split peas, *a* - -	26.3	0.9	61.4	1,729	455	16	1,062
Pears and apples (25 % refuse), - - -	0.3	0.4	15.9	18,541	56	74	2,948
Cranberries, - -	0.4	0.9	10.9	440	2	4	48
Raisins and prunes, -	2.7	0.7	71.6	653	18	5	468
Rice, - - - -	7.4	0.4	79.4	680	50	3	540
Farina and sago, - -	—	—	97.8	993	—	—	971
Oatmeal, - - -	14.7	7.1	68.4	1,134	167	81	776
Buckwheat flour, - -	6.9	1.4	76.1	3,062	211	43	2,330
Rye flour, - - -	6.7	0.8	78.7	1,191	80	10	937
Wheat flour, *a* - -	13.8	1.2	71.7	27,159	3,748	326	19,472
Bread, - - -	9.1	1.6	56.0	3,232	294	52	1,810
Drop cakes, *a* - -	7.7	14.7	60.3	1,814	140	267	1,094
Sugar, - - - -	—	—	97.8	12,573	—	—	12,295
Molasses, - - -	—	—	73.1	57	—	—	42
Chocolate, - - -	6.2	21.0	69.0	340	21	71	235
Cream crackers, *a* -	9.3	13.1	69.2	1,247	116	163	863
Total vegetable food,				113,947	6,162	1,176	52,707
Total animal & vegetable food purchased, -				207,027	12,792	20,349	54,601
TABLE AND KITCHEN WASTES, - - -	9.4	29.8	55.7	1,367	128	408	761

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 48.

Weights and Percentages of Food Materials and Nutritive Ingredients Used in Dietary of a Machinist's Family.

KINDS OF FOOD MATERIALS.	WEIGHT IN GRAMS.				WEIGHT IN POUNDS.			
	Food Materials.	Nutrients.			Food Materials.	Nutrients.		
		Protein.	Fats.	Carbo-hydrates.		Protein.	Fats.	Carbo-hydrates.
For Family, 30 Days.	Grams.*	Grams	Grams	Grams	Lbs.	Lbs.	Lbs.	Lbs.
Meats,	38,328	4,823	12,194	—	85	11	27	—
Fish,	1,077	88	2	—	2	—	—	—
Dairy products, Butter,	5,046	—	4,289	—	11	—	9	—
Milk,	47,343	1,563	2,557	1,894	104	3	6	4
Total,	52,389	1,563	6,846	1,894	115	3	15	4
Eggs,	1,286	156	131	—	3	—	—	—
Total animal food,	93,080	6,630	19,173	1,894	205	14	42	4
Vegetable food,	113,947	6,162	1,176	52,707	251	14	3	116
Total animal and vegetable food,	207,027	12,792	20,349	54,601	456	28	45	120
Per Man per Day.								
Meats,	300	37.7	95.3	—	.667	.083	.210	—
Fish,	8	.7	—	—	.015	.001	—	—
Dairy products, Butter,	39	—	33.5	—	.085	—	.074	—
Milk,	370	12.2	20.0	14.8	.812	.027	.044	.032
Total,	409	12.2	53.5	14.8	.897	.027	.118	.032
Eggs,	10	1.2	1.0	—	.023	.003	.002	—
Total animal food,	727	51.8	149.8	14.8	1.602	.114	.330	.032
Vegetable food,	890	48.1	9.2	411.8	1,960	.106	.020	.908
Total food,	1,617	99.9	159.0	426.6	.3562	.220	.350	.940
Percentages of Total Food Purchased.	%	%	%	%				
Meats, etc.,	18.5	37.7	59.9	—	—	—	—	—
Fish,	.5	.7	—	—	—	—	—	—
Dairy products, Butter,	2.4	—	21.1	—	—	—	—	—
Milk,	22.9	12.2	12.6	3.5	—	—	—	—
Total,	25.3	12.2	33.7	3.5	—	—	—	—
Eggs,	.6	1.2	.6	—	—	—	—	—
Total animal food,	44.9	51.8	94.2	3.5	—	—	—	—
Vegetable food,	55.1	48.2	5.8	96.5	—	—	—	—
Total food,	100.0	100.0	100.0	100.0	—	—	—	—

*100 grams=3.5 ounces, or .22 pounds. 1 ounce=28.35 grams. 1 pound=453.6 grams.

TABLE 49.

Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of a Machinist's Family.

		NUTRIENTS.			Potential Energy.
		Protein.	Fats.	Carbo-hydrates.	
For Family, 30 Days.		Grams.*	Grams.	Grams.	Calories.
Food purchased.	Animal, - - -	6,630	19,173	1,894	213,255
	Vegetable, - -	6,162	1,176	52,707	252,300
	Total, - - -	12,792	20,349	54,601	465,555
Waste, - -	Animal, - - -	39	391	—	3,795
	Vegetable, - -	89	17	761	3,645
	Total, - - -	128	408	761	7,440
Food actually eaten,	Animal, - - -	6,591	18,782	1,894	209,460
	Vegetable, - -	6,073	1,159	51,946	248,655
	Total, - - -	12,664	19,941	53,840	458,115
Per Man per Day.					
Food purchased,	Animal, - - -	52	150	15	1,670
	Vegetable, - -	48	9	412	1,970
	Total, - - -	100	159	427	3,640
Waste, - -	Animal, - - -	—	3	—	30
	Vegetable, - -	1	—	6	30
	Total, - - -	1	3	6	60
Food actually eaten,	Animal, - - -	52	147	15	1,640
	Vegetable, - -	47	9	406	1,940
	Total, - - -	99	156	421	3,580
Percentage of Total Food Purchased.		%	%	%	%
Food purchased,	Animal, - - -	51.8	94.2	3.5	45.8
	Vegetable, - -	48.2	5.8	96.5	54.2
	Total, - - -	100.0	100.0	100.0	100.0
Waste, - -	Animal, - - -	0.3	1.9	—	0.8
	Vegetable, - -	0.7	0.1	1.4	0.8
	Total, - - -	1.0	2.0	1.4	1.6
Food actually eaten,	Animal, - - -	51.3	92.3	3.5	45.0
	Vegetable, - -	47.7	5.7	95.1	53.4
	Total, - - -	99.0	98.0	98.6	98.4

*100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

DIETARY OF A MASON'S FAMILY.

The study began Nov. 26, 1892, and continued 28 days. The family was as follows:—

Man about 28 years old (mason), at work three of the four weeks.

Woman of about same age (assumed = .8 of one man).

Child of 7 months (assumed = .25 of one man).

The meals taken were equivalent to 172 meals, or 57 days for one man.

TABLE 50.

Food Materials and Table and Kitchen Wastes in Dietary of a Mason's Family During Twenty-eight Days.

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbohydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbohydrates.
ANIMAL FOODS.	%	%	%	Grams*	Grams	Grams	Grams
Beef.							
Shoulder,	17.0	13.7	—	4,100	697	561	—
Round,	18.0	12.3	—	1,250	225	154	—
Leg free from bone,	21.0	5.7	—	880	185	50	—
Dried Beef,	28.8	4.4	—	260	75	11	—
Bologna sausage,	18.8	15.8	—	280	53	44	—
Total,				6,770	1,235	820	—
Pork.							
Spare rib, *a*	17.0	30.4	—	2,520	428	770	—
Sausage,	13.8	42.8	—	1,560	215	668	—
Ham (smoked),	14.8	34.6	—	2,520	373	872	—
Salt pork,	.9	82.8	—	2,310	20	1,913	—
Lard,	—	99.8	—	940	—	938	—
Total,				9,850	1,036	5,161	—
Fish, Etc.							
Canned salmon,	20.1	15.7	—	2,420	486	380	—
Pickled herring,	18.5	11.0	—	1,990	358	219	—
Clams in shell,	2.1	1.0	1.3	1,730	36	2	22
Total,				6,140	880	601	22

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* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 50.—*(Continued.)*

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbohydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbohydrates.
Dairy Products, Etc.	%	%	%	Grams*	Grams	Grams	Grams
Butter,	—	85.0	—	1,130	—	1,130	—
Milk,	3.6	4.0	4.7	15,880	569	635	746
Total,				17,210	569	1,765	746
Eggs,	12.1	10.2	—	1,390	168	142	—
Total animal food,				41,360	3,888	8,489	768
VEGETABLE FOODS.							
Potatoes (15 % refuse),	2.1	.1	17.9	18,500	389	18	3,312
Sweet potatoes (12.5 % refuse),	1.5	.4	26.0	1,370	21	5	382
Onions (10 % refuse),	1.4	.3	10.1	510	6	2	52
Turnips (30 % refuse),	1.2	.2	8.2	3,140	38	6	257
Apples (25 % refuse),	.3	.4	15.9	3,620	11	14	576
Raisins and prunes,	2.7	.7	71.6	1,370	37	9	981
Starch, etc.,	—	—	97.8	760	—	—	743
Oatmeal,	14.7	7.1	68.4	210	32	15	146
Flour, *a*	13.2	1.2	73.1	9,530	1,258	114	6,966
Rye flour, *a*	12.0	1.2	74.2	3,520	422	42	2,612
Sugar, "extra C," *a*	—	—	95.0	2,280	—	—	2,166
Sugar, granulated, *a*	—	—	100.0	5,500	—	—	5,500
Total,				50,310	2,214	216	21,527
Total animal and vegetable foods purchased,				91,670	6,102	8,705	22,295
TABLE AND KITCHEN WASTES,	12.9	21.6	62.1	1,244	161	269	772

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 51.

Weights and Percentages of Food Materials and Nutritive Ingredients Used in Dietary of a Mason's Family.

KINDS OF FOOD MATERIALS.	WEIGHT IN GRAMS.				WEIGHT IN POUNDS.			
	Food Materials.	Nutrients.			Food Materials.	Nutrients.		
		Protein.	Fat.	Carbo-hydrates.		Protein.	Fat.	Carbo-hydrates.
For Family, 28 Days.	Grams.*	Grams	Grams	Grams	Lbs.	Lbs.	Lbs.	Lbs.
Meats, etc.,	16,620	2,271	5,981	—	36.6	5.0	13.2	—
Fish, etc.,	6,140	880	601	22	13.5	1.9	1.3	—
Dairy products, Butter,	1,330	—	1,130	—	2.9	—	2.5	—
Dairy products, Milk,	15,880	569	635	746	35.0	1.3	1.4	1.6
Dairy products, Total,	17,210	569	1,765	746	37.9	1.3	3.9	1.6
Eggs,	1,390	168	142	—	3.1	.4	.3	—
Total animal food,	41,360	3,888	8,489	768	91.1	8.6	18.7	1.6
Vegetable food,	50,310	2,214	216	21,527	110.9	4.9	.5	47.4
Total food,	91,670	6,102	8,705	22,295	202.0	13.5	19.2	49.0
Per Man per Day.								
Meats, etc.,	292	40	105	—	.65	.09	.23	—
Fish, etc.,	108	15	10	—	.23	.03	.02	—
Dairy products, Butter,	23	—	20	—	.05	—	.04	—
Dairy products, Milk,	279	10	11	13	.62	.02	.03	.03
Dairy products, Total,	302	10	31	13	.67	.02	.07	.03
Eggs,	24	3	3	—	.05	.01	.01	—
Total animal food,	726	68	149	13	1.60	.15	.33	.03
Vegetable food,	883	39	4	378	1.94	.09	—	.83
Total food,	1,609	107	153	391	3.54	.24	.33	.86
Percentages of Total Food Purchased.	%	%	%	%				
Meats, etc.,	18.2	37.3	68.7	—	—	—	—	—
Fish, etc.,	6.7	14.4	6.9	—	—	—	—	—
Dairy products, Butter,	1.4	—	13.0	—	—	—	—	—
Dairy products, Milk,	17.4	9.3	7.3	3.5	—	—	—	—
Dairy products, Total,	18.8	9.3	20.3	3.5	—	—	—	—
Eggs,	1.4	2.7	1.6	—	—	—	—	—
Total animal food,	45.1	63.7	97.5	3.4	—	—	—	—
Vegetable food,	54.9	36.3	2.5	96.6	—	—	—	—
Total food,	100.0	100.0	100.0	100.0	—	—	—	—

*100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 52.

Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of a Mason's Family.

		Nutrients.			Potential Energy.
		Protein.	Fat.	Carbo-hydrates.	
For Family, 28 Days.		Grams*	Grams	Grams.	Calor's.
Food purchased, -	Animal, - -	3,888	8,489	768	98,040
	Vegetable, - -	2,214	216	21,527	99,350
	Total, - - -	6,102	8,705	22,295	197,390
Waste, - - -	Animal, - -	144	206	—	3,060
	Vegetable, - -	17	3	772	3,260
	Total, - - -	161	269	772	6,320
Food actually eaten,	Animal, - -	3,744	8,223	768	94,980
	Vegetable, - -	2,197	213	20,755	96,090
	Total, - - -	5,941	8,436	21,523	191,070
Per Man per Day.					
Food purchased -	Animal, - -	68	149	13	1,720
	Vegetable, - -	39	4	378	1,750
	Total, - - -	107	153	391	3,470
Waste, - - -	Animal, - -	3	5	—	60
	Vegetable, - -	—	—	16	60
	Total, - - -	3	5	16	120
Food actually eaten,	Animal, - -	65	144	13	1,660
	Vegetable, - -	39	4	362	1,690
	Total, - - -	104	148	375	3,350
Percentage of Total Food Purchased.		%	%	%	%
Food purchased, -	Animal, - -	63.7	97.5	3.4	49.7
	Vegetable, - -	36.3	2.5	96.6	50.3
	Total, - - -	100.0	100.0	100.0	100.0
Waste, - - -	Animal, - -	2.3	3.1	—	1.5
	Vegetable, - -	.3	—	3.5	1.6
	Total, - - -	2.6	3.1	3.5	3.1
Food actually eaten,	Animal, - -	61.4	94.5	3.4	48.2
	Vegetable, - -	36.0	2.4	93.1	48.7
	Total, - - -	97.4	96.9	96.5	96.9

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

DIETARY OF A CARPENTER'S FAMILY.

The study began Nov. 25, 1892, and continued 28 days. The family was as follows:—

Man (carpenter), about 25 years old, at work.

Woman, about 25 years old (assumed = .8 of one man).

Boy, about 2 years old (assumed = .5 of one man).

The meals taken were equivalent to 205 meals, or 68 days for one man.

TABLE 53.

Food Materials and Table and Kitchen Wastes in Dietary of a Carpenter's Family During Twenty-eight Days.

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
					Nutrients.		
	Protein.	Fat.	Carbo-hydrates.	Total Food Materials.	Protein.	Fat.	Carbo-hydrates.
ANIMAL FOODS.	%	%	%	Grams*	Grams	Grams	Grams
Beef.							
Shoulder,	17.0	13.7	—	3,420	581	469	—
Leg free from bone,	21.0	5.7	—	480	101	27	—
Sirloin,	15.0	16.4	—	850	128	139	—
Round,	18.0	12.3	—	850	153	105	—
Ribs,	12.2	27.9	—	1,310	160	366	—
Suet,	.9	94.6	—	90	1	85	—
Frankfort sausage	18.8	15.8	—	990	186	156	—
Total,				7,990	1,310	1,347	—
Veal.							
Shoulder,	18.3	5.5	—	1,930	353	106	—
Total,				1,930	353	106	—
Pork.							
Chops, *a*	17.0	30.4	—	6,950	1,182	2,113	—
Sausage,	13.8	42.8	—	2,520	348	1,079	—
Ham, smoked,	14.8	34.6	—	3,240	480	1,121	—
Salt pork,	.9	82.8	—	70	1	58	—
Lard, *a*	—	99.8	—	1,230	—	1,228	—
Total,				14,010	2,011	5,599	—
Poultry.							
Chicken,	15.1	1.2	—	1,360	205	16	—
Total,				1,360	205	16	—

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* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 53.—*(Continued.)*

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo-hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo-hydrates.
Fish.	%	%	%	Grams*	Grams	Grams	Grams
Boneless salt cod, -	22.2	.3	—	440	98	1	—
Total, - - -				440	98	1	—
Dairy Products, Etc.							
Butter, - - -	—	85.0	—	2,070	—	1,760	—
Whole milk, *a* - -	4.4	5.8	4.4	15,860	698	920	698
Skimmed milk, *a* - -	3.9	.5	4.6	18,140	708	91	835
Total, - - -				36,070	1,406	2,771	1,533
Eggs, - - - -	12.1	10.2	—	1,260	153	129	—
Total animal food, -				63,060	5,536	9,969	1,533
VEGETABLE FOODS.							
Potatoes (15 % refuse), -	2.1	.1	17.9	18,530	389	19	3,317
Sweet potatoes (12.5 % refuse), - - -	1.5	.4	26.0	1,400	21	6	364
Onions (10 % refuse), -	1.4	.3	10.1	2,200	31	7	222
Turnips (30 % refuse), -	1.2	.2	8.2	3,900	47	8	320
Cabbage (15 % refuse), -	1.5	.2	4.6	890	13	2	41
Canned squash, - -	.9	.2	10.1	990	9	2	100
Apples (25 % refuse), -	.3	.4	15.9	10,450	31	42	1,662
Grapes (25 % refuse), -	1.7	1.7	21.3	1,430	24	24	305
Dried Beans, - -	23.1	2.0	59.2	1,960	453	39	1,160
Starch, etc., - -	—	—	97.8	520	—	—	509
Rice, - - - -	7.4	.4	79.4	370	27	2	294
Flour, *a* - - -	12.2	1.1	72.3	16,010	1,953	176	11,575
Sugar, *a* - - -	—	—	100.0	11,170	—	—	11,170
Molasses, *a* - - -	—	—	72.0	1,790	—	—	1,289
Total vegetable food,				71,610	2,998	327	32,328
Total animal and vegetable food purchased, - - -				134,670	8,534	10,296	33,861
TABLE AND KITCHEN WASTES, - - -	21.6	31.8	42.0	3,653	790	1,161	1,536

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 54.

Weights and Percentages of Food Materials and Nutritive Ingredients Used in Dietary of a Carpenter's Family.

KINDS OF FOOD MATERIALS.	WEIGHT IN GRAMS.				WEIGHT IN POUNDS.			
		Nutrients.				Nutrients.		
	Food Materials.	Protein.	Fat.	Carbo-hydrates.	Food Materials.	Protein.	Fat.	Carbo-hydrates.
For Family, 28 Days.	Grams*	Grams	Grams	Grams	Lbs.	Lbs.	Lbs.	Lbs.
Meats, etc., - - -	25,290	3,879	7,068	—	55.8	8.6	15.6	—
Fish, etc., - - -	440	98	1	—	1.0	.2	—	—
Dairy products, Butter, -	2,070	—	1,760	—	4.5	—	3.9	—
Milk, -	34,000	1,406	1,011	1,533	75.0	3.1	2.2	3.4
Total, -	36,070	1,406	2,771	1,533	79.5	3.1	6.1	3.4
Eggs, - - - -	1,260	153	129	—	2.8	.3	.3	—
Total animal food, -	63,060	5,536	9,969	1,533	139.1	12.2	22.0	3.4
Vegetable food, -	71,610	2,998	327	32,328	157.8	6.6	.7	71.2
Total food, - -	134,670	8,534	10,296	33,861	296.9	18.8	22.7	74.6
Per Man per Day.								
Meats, etc., - -	373	57	104	—	.82	.13	.22	—
Fish, etc., - - -	6	1	—	—	.01	—	—	—
Dairy products, Butter, -	30	—	26	—	.07	—	.06	—
Milk, -	500	21	15	23	1.10	.04	.03	.05
Total, -	530	21	41	23	1.17	.04	.09	.05
Eggs, - - - -	18	2	2	—	.04	.01	.01	—
Total animal food, -	927	81	147	23	2.04	.18	.32	.05
Vegetable food, -	1,053	44	5	475	2.32	.09	.01	1.05
Total food, - -	1,980	125	152	498	4.36	.27	.33	1.10
Percentages of Total Food Purchased.	%	%	%	%				
Meats, etc., - -	18.9	45.5	68.6	—	—	—	—	—
Fish, etc., - - -	.3	1.1	—	—	—	—	—	—
Dairy products, Butter, -	1.5	—	17.0	—	—	—	—	—
Milk, -	25.2	16.5	9.8	4.5	—	—	—	—
Total, -	26.7	16.5	26.8	4.5	—	—	—	—
Eggs, - - - -	.9	1.8	1.3	—	—	—	—	—
Total animal food, -	46.8	64.9	96.7	4.5	—	—	—	—
Vegetable food, -	53.2	35.1	3.3	95.5	—	—	—	—
Total food, - - -	100.0	100.0	100.0	100.0	—	—	—	—

*100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 55.

Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of a Carpenter's Family.

		Nutrients.			Potential Energy.
		Protein.	Fats.	Carbo-hydrates.	
For Family, 28 Days.		Grams.*	Grams.	Grams.	Calories.
Food purchased,	Animal,	5,536	9,969	1,533	121,690
	Vegetable,	2,998	327	32,328	147,880
	Total,	8,534	10,296	33,861	269,570
Waste,	Animal,	643	1,146	—	13,290
	Vegetable,	147	15	1,536	7,040
	Total,	790	1,161	1,536	20,330
Food actually eaten,	Animal,	4,893	8,823	1,533	108,400
	Vegetable,	2,851	312	30,792	140,840
	Total,	7,744	9,135	32,325	249,240
Per Man per Day.					
Food purchased,	Animal,	81	147	23	1,790
	Vegetable,	44	5	475	2,180
	Total,	125	152	498	3,970
Waste,	Animal,	9	17	—	200
	Vegetable,	2	—	23	100
	Total,	11	17	23	300
Food actually eaten,	Animal,	72	130	23	1,590
	Vegetable,	42	5	452	2,080
	Total,	114	135	475	3,670
Percentage of Total Food Purchased.		%	%	%	%
Food purchased,	Animal,	64.9	96.7	4.5	45.2
	Vegetable,	35.1	3.3	95.5	54.8
	Total,	100.0	100.0	100.0	100.0
Waste,	Animal,	7.6	11.1	—	5.0
	Vegetable,	1.7	0.1	4.5	2.6
	Total,	9.3	11.2	4.5	7.6
Food actually eaten,	Animal,	57.3	85.6	4.5	40.2
	Vegetable,	33.4	3.2	91.0	52.2
	Total,	90.7	88.8	95.5	92.4

*100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

DIETARY OF A CARPENTER'S FAMILY.

The study began Nov. 26, 1892, and continued 28 days. The family was as follows:—

Man (carpenter) about 35 years old, at work.
Woman of about same age (assumed = .8 of one man).
Boy about 11 years old (assumed = .7 of one man).
The meals taken were equivalent to 210 meals, or 70 days for one man.

TABLE 56.

Food Materials and Table and Kitchen Wastes in Dietary of a Carpenter's Family During Twenty-eight Days.

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo-hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo-hydrates.
ANIMAL FOODS.	%	%	%	Grams*	Grams	Grams	Grams
Beef.							
Sirloin, - - - -	15.0	16.4	—	1,900	285	312	—
Leg, free from bone, -	21.0	5.7	—	4,100	861	234	—
Dried Beef, - - -	28.8	4.4	1.4	230	66	10	3
Frankfort sausage, -	18.8	15.8	—	370	70	58	—
Liver, - - - -	20.1	5.4	3.5	450	90	24	16
Total, - - -				7,050	1,372	638	19
Lamb.							
Chop, - - -	16.7	22.1	—	680	114	150	—
Pork.							
Spare rib, *a* - -	17.0	30.4	—	1,910	324	580	—
Sausage, - - -	13.8	42.8	—	1,970	272	843	—
Ham, - - - -	14.8	34.6	—	1,870	277	647	—
Salt pork, - - -	.9	82.8	—	1,020	9	845	—
Lard, *a* - - -	—	99.8	—	3,000	—	2,994	—
Total, - - -				9,770	882	5,909	—
Poultry.							
Turkey, free from bone,	23.9	8.7	—	2,210	528	192	—

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* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 56.—*(Continued.)*

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo-hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo-hydrates.
Fish.	%	%	%	Grams*	Grams	Grams	Grams
Salt cod, - - -	16.0	.4	—	1,470	235	6	—
Total fish, - -				1,470	235	6	—
Dairy Products, Etc.							
Butter, - - -	—	85.0	—	3,150	—	2,678	—
Milk, - - - -	3.6	4.0	4.7	13,830	498	553	650
Cheese, - - -	28.3	35.5	1.8	1,490	422	529	27
Total, - - -				18,470	920	3,760	677
Eggs, - - - -	12.1	10.2	—	760	92	78	—
Total, - - -				760	92	78	—
Total animal food, -				40,410	4,143	10,733	696
VEGETABLE FOODS.							
Potatoes (15 % refuse), -	2.1	.1	17.9	31,620	664	32	5,660
Sweet potatoes (12.5 % refuse), - - -	1.5	.4	26.0	2,260	34	8	588
Turnips (30 % refuse), -	1.2	.2	8.2	7,990	96	16	655
Canned squash, - -	.9	.2	10.1	1,030	9	2	104
Apples (25 % refuse), -	.3	.4	15.9	4,000	12	16	636
Grapes (25 % refuse), -	1.7	1.7	21.3	1,100	19	19	234
Beans, dried, - -	23.1	2.0	59.2	870	200	17	516
Raisins, - - -	2.7	.7	71.5	430	16	3	303
Starch, - - -	—	—	97.8	280	—	—	279
Rice, - - - -	7.4	.4	79.4	150	11	—	119
Mince meat, "None-such," *a* - -	4.0	2.2	67.4	1,370	55	30	923
Flour, *a* - - -	12.0	1.2	74.2	6,920	830	83	5,135
Buckwheat flour, - -	6.9	1.4	76.1	1,300	90	18	989
Bread, - - -	9.1	1.6	56.0	13,690	1,246	219	7,666
Cake, - - - -	8.3	10.8	57.6	890	74	96	512
Sugar, extra C, *a* - -	—	—	95.0	3,730	—	—	3,543
Total vegetable food,	—	—	—	77,630	3,356	559	27,862
Total animal & vegetable food purchased, -	—	—	—	118,040	7,499	11,292	28,558
TABLE AND KITCHEN WASTES, - - -	17.0	29.2	50.1	2,805	477	821	1,405

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 57.

Weights and Percentages of Food Materials and Nutritive Ingredients Used in Dietary of a Carpenter's Family.

KINDS OF FOOD MATERIALS.	WEIGHT IN GRAMS.				WEIGHT IN POUNDS.			
		Nutrients.				Nutrients.		
	Food Materials.	Protein.	Fats.	Carbo-hydrates.	Food Materials.	Protein.	Fats.	Carbo-hydrates.
For Family, 28 Days.	Grams*	Grams	Grams	Grams	Lbs.	Lbs.	Lbs.	Lbs.
Meats, etc.,	19,710	2,896	6,889	19	43.6	6.4	15.2	—
Fish,	1,470	235	6	—	3.2	.5	—	—
Dairy products, Butter,	3,150	—	2,678	—	6.9	—	5.9	—
Milk,	13,830	498	553	650	30.5	1.1	1.2	1.4
Cheese,	1,490	422	529	27	3.3	.9	1.2	.1
Total,	18,470	920	3,760	677	40.7	2.0	8.3	1.5
Eggs,	760	92	78	—	1.7	.2	.2	—
Total animal food,	40,410	4,143	10,733	696	89.2	9.1	23.7	1.5
Vegetable food,	77,630	3,356	559	27,862	171.1	7.4	1.2	61.5
Total food,	118,040	7,499	11,292	28,558	260.3	16.5	24.9	63.0
Per Man per Day.								
Meats,	281	42	98	—	.62	.10	.21	—
Fish,	21	3	—	—	.05	—	—	—
Dairy products, Butter,	45	—	38	—	.10	—	.08	—
Milk,	198	7	8	9	.44	.02	.02	.02
Cheese,	21	6	8	1	.04	.01	.02	—
Total,	264	13	54	10	.58	.03	.12	.02
Eggs,	11	1	1	—	.02	—	—	—
Total animal food,	577	59	153	10	1.27	.13	.33	.02
Vegetable food,	1,109	48	8	398	2.45	.11	.02	.88
Total food,	1,686	107	161	408	3.72	.24	.35	.90
Percentages of Total Food Purchased.	%	%	%	%				
Meats, etc.,	16.7	38.6	61.1	—	—	—	—	—
Fish,	1.2	3.1	—	—	—	—	—	—
Dairy products, Butter,	2.7	—	23.9	—	—	—	—	—
Milk,	11.7	6.6	4.8	2.3	—	—	—	—
Cheese,	1.2	5.7	4.6	.1	—	—	—	—
Total,	15.6	12.3	33.3	2.4	—	—	—	—
Eggs,	.7	1.2	.7	—	—	—	—	—
Total animal food,	34.2	55.2	95.1	2.4	—	—	—	—
Vegetable food,	65.8	44.8	4.9	97.6	—	—	—	—
Total food,	100.0	100.0	100.0	100.0	—	—	—	—

*100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 58.

Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of a Carpenter's Family.

		NUTRIENTS.			Potential Energy.
		Protein.	Fats.	Carbo-hydrates.	
For Family, 28 Days.		Grams.*	Grams.	Grams.	Calories.
Food purchased,	Animal,	4,143	10,733	696	119,670
	Vegetable,	3,356	559	27,862	133,190
	Total,	7,499	11,292	28,558	252,860
Waste,	Animal,	420	805	—	9,210
	Vegetable,	57	16	1,405	6,110
	Total,	477	821	1,405	15,320
Food actually eaten,	Animal,	3,723	9,928	696	110,460
	Vegetable,	3,299	543	26,457	127,080
	Total,	7,022	10,471	27,153	237,540
Per Man per Day.					
Food purchased,	Animal,	59	153	10	1,710
	Vegetable,	48	8	398	1,900
	Total,	107	161	408	3,610
Waste,	Animal,	6	12	—	140
	Vegetable,	1	—	20	80
	Total,	7	12	20	220
Food actually eaten,	Animal,	53	141	10	1,570
	Vegetable,	47	8	378	1,820
	Total,	100	149	388	3,390
Percentages of Total Food Purchased.		%	%	%	%
Food purchased,	Animal,	55.2	95.1	2.4	47.3
	Vegetable,	44.8	4.9	97.6	52.7
	Total,	100.0	100.0	100.0	100.0
Waste,	Animal,	5.6	7.1	—	3.6
	Vegetable,	0.8	0.1	4.9	2.4
	Total,	6.4	7.2	4.9	6.0
Food actually eaten,	Animal,	49.6	88.0	2.4	43.7
	Vegetable,	44.6	4.8	92.7	50.3
	Total,	93.6	92.8	95.1	94.0

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* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 59.

Summary of Results of Dietary Studies made by Station.—Food per Man per Day.

		NUTRIENTS.			Potential Energy.
		Protein.	Fat.	Carbo-hydrates.	
1. Dietary of a Boarding House.†		Grams.*	Grams.	Grams.	Calories.
Food,	Purchased,	126	188	426	4,010
	Waste,	23	36	25	520
	Eaten,	**103**	**152**	**401**	**3,490**
2. Dietary of a Chemist's Family.†					
Food purchased,‡		**118**	**103**	**430**	**3,210**
3. Dietary of a Jeweler's Family.					
Food,	Purchased,	91	126	483	3,530
	Waste,	8	9	5	140
	Eaten,	**83**	**117**	**478**	**3,390**
4. Dietary of a Blacksmith's Family.					
Food,	Purchased,	103	176	408	3,730
	Waste,	3	5	7	90
	Eaten,	**100**	**171**	**401**	**3,640**
5. Dietary of a Machinist's Family.					
Food,	Purchased,	100	159	427	3,640
	Waste,	1	3	6	60
	Eaten,	**99**	**156**	**421**	**3,580**
6. Dietary of a Mason's Family.					
Food,	Purchased,	107	153	391	3,470
	Waste,	3	5	16	120
	Eaten,	**104**	**148**	**375**	**3,350**
7. Dietary of a Carpenter's Family.					
Food,	Purchased,	125	152	498	3,970
	Waste,	11	17	23	300
	Eaten,	**114**	**135**	**475**	**3,670**
8. Dietary of a Carpenter's Family.					
Food,	Purchased,	107	161	408	3,610
	Waste,	7	12	20	220
	Eaten,	**100**	**149**	**388**	**3,390**
Food eaten,	Minimum of above,	83	103	375	3,210
	Maximum of above,	118	171	478	3,640
	Average of above,	**103**	**141**	**421**	**3,460**
Dietary standards for men at moderate work,	Voit (German),	**118**	**56**	**500**	**3,060**
	Atwater (American),	**125**	**125**	**450**	**3,560**

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* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.
† Report of this Station 1891, pages 00–106.
‡ There was very little "waste" in this dietary.

ECONOMY OF FOOD.

BY W. O. ATWATER.

Food constitutes the chief item of the living expenses of the people, of our agricultural production, and of our export to Europe. Wage-workers and people of moderate incomes generally spend, and must spend, more than half their earnings for food. Nevertheless, they do not understand either the relation of the nutritive value of food to its cost, or its physiological effects. The result is great waste in the purchase and use of food, loss of money and injury to health.

NUTRITIVE VALUES OF FOODS.

A pound of lean beef and a quart of whole milk contain about the same amounts of actually nutritive material. But the pound of beef costs more than the quart of milk, and its nutrients not only differ in number and kind, but are, for ordinary use, more valuable than those of the milk. This illustrates a fundamental fact in the economy of foods, namely, that the differences in the values of different foods depend upon both the kinds and the amounts of the nutritive materials which they contain. Add to this that it is essential for health that the food shall supply the nutrients in the kinds and the proportions required by the body, and that it is likewise important, from a pecuniary standpoint, that the materials be obtained at the minimum cost, and we have the fundamental principles of food economy.

In the last Annual Report of this Station* detailed accounts were given of a series of investigations of the chemical composition and nutritive values of common kinds of food, and of the amounts of food and of nutritive ingredients in a number of dietaries of people in various conditions of life in the United States and in Europe. A preceding chapter in the present report (pp. 135–162,) describes a continuation of the study of dietaries. The purpose of the present article is to call attention in more detail to some points which bear upon the economical use of food. As the subject is comparatively new to most readers, and this Report will fall into the hands of many who are not familiar with the latest teachings of chemistry and physiology, some explanations may not be out of place.

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*See also Bulletin No. 6 of the Station on the Chemistry and Economy of Foods, and report of U. S. Fish Commission for 1888 (Washington, 1892), pp. 817–868.

THE NUTRITIVE INGREDIENTS OF FOOD.

Edible Portion and Refuse.—If the reader will take the pains to notice the next piece of beef that he has to carve for dinner, he will, of course, observe first of all that, along with the meat which is good to eat, there is more or less bone, which, except in so far as it may be used for soup, is of no value for food. The beef, then, may be regarded as consisting of edible portion and refuse. The same is true of fish. In eggs there is a corresponding distinction between shells and the so-called "meat," and oysters and other shellfish in like manner include the shells, which are simply refuse, and the shell contents which make up the edible portion. The inside of the potato and the wheat flour are the edible portion, and the skin and bran are refuse of potatoes and wheat.

If we weigh the whole meat, bone and all, to start with, and afterwards weigh bone and other refuse and the meat, we can easily calculate the percentages of refuse and edible portion. If we then determine the percentages of water, water-free substance in the meat, as we can do by drying the water out and weighing the dried residue; and then burn the latter and weigh the ash which is left, we have made a fair start in the analysis for determining the value for nourishment.

Nutrients.—The water-free substance contains all of the nutritive materials, or nutrients, but the analysis thus far has told only the percentage of ash, or mineral matters. The proportions of the other ingredients must be found out before we can judge exactly of the food value.

Protein.—The meat consists of lean and fat. Part of the fat is in large lumps, which can be easily separated from the lean. Indeed, we often cut out the fat of the meat which is served on our plates at the table, and reject it instead of eating it. But a portion of the fat is in very fine particles diffused throughout the lean. Much of this finely divided fat is in particles so small as to be invisible to the naked eye, but it is possible to separate them very completely from the lean by processes of analysis common in the laboratory. After the water and the fat have been removed from the lean meat the material which remains will contain a little mineral matter, which would be left as ash if it were burned; the rest consists chiefly of so-called protein compounds. The protein is the chief nutritive constituent of fish and eggs, as well as of lean meat. It occurs also in milk and in vegetable foods, such as wheat, corn, potatoes, etc.

Fat.—Fat is familiar to us in meat, from which we get it in the form of tallow and lard; in milk, from which it is obtained as butter; and in the various oils, such as olive oil, cotton-seed oil, and the oils of wheat and corn. Larger or smaller proportions of fat are found in most food materials.

Carbohydrates.—Potatoes, wheat, and corn contain large proportions of starch. Sugar cane and sorghum are rich in sugar. Starch and sugar are very similar in chemical composition, and are called carbohydrates. Other carbohydrates are found in animals and plants, such as glycogen or "animal starch," which is found in the liver, and cellulose, which occurs in plants.

Ash.—The mineral matter, or ash, which is left behind when animal or vegetable matter is burned, consists of a variety of chemical compounds commonly called salts, and including phosphates, sulphates, and chlorides of the metals calcium, magnesium, potassium, and sodium. Calcium phosphate, or phosphate of lime, is the chief mineral constituent of bone. Common salt is chloride of sodium.

For nourishment we need all of the different classes of nutrients and in proper proportions. Thus a day's food for an average man doing moderately hard muscular work may appropriately supply on the average, about 4⅓ ounces of protein, the same quantity of fats, and 16 ounces of carbohydrates.

To recapitulate briefly : From the standpoint of their uses in the nutrition of man, the constituents of ordinary foods may be classified as follows:—

Edible substance, as the flesh of meats and fish, the shell contents of oysters, wheat flour.

Refuse, as bones of meat and fish, the shells of oysters, bran of wheat.

The edible substance consists of (1) water, (2) nutritive substance, or nutrients.

The water, refuse, and the salt of salted meat and fish are called non-nutrients. The water contained in foods and beverages has the same composition and properties as other water; it is, of course, indispensable for nourishment, but it is not a nutrient in the sense in which it is here used. In comparing the values of different food materials for nourishment, the refuse and water are left out of account.

Classes of Nutrients.

The following are familiar examples each of the four principal classes of nutrients:—

Protein, - -	Albuminoids: *e. g.*, albumen (white of eggs); casein (curd) of milk; myosin, the basis of muscle (lean meat); gluten of wheat, etc. Gelatinoids: *e. g.*, collagen of tendons; ossein of bones, which yield gelatine or glue, etc. Meats and fish contain very small quantities of so-called "extractives." They include kreatin and allied compounds, and are the chief ingredients of beef-tea and meat extract. They contain nitrogen, and hence are commonly classed with protein.
Fats, - -	*e. g.*, fat of meat; fat (butter) of milk; olive oil; oil of corn, wheat, etc.
Carbohydrates, -	*e. g.*, sugar, starch, cellulose (woody fiber), etc.
Mineral Matters,	*e. g.*, calcium phosphate or phosphate of lime, sodium chloride (common salt), etc.

HOW FOOD IS USED IN THE BODY.

The two chief uses of food of animals are: First, to form the material of the body and make up its wastes; and, second, to yield energy in the form of heat to keep the body warm and muscular and other power for the work it has to do. In forming the tissues and fluids of the body the food serves for building and repair. In yielding energy it serves as fuel.

The different nutrients of food act in different ways in fulfilling these purposes. The principal tissue formers are the protein compounds. These form the framework of the body. They build up and repair the nitrogenous materials, as the muscle and bone, and supply the albuminoids of blood, milk and other fluids. The chief fuel-ingredients of the food are the carbohydrates and fats. These are either consumed in the body, or are stored as fat to be used as occasion demands. In being used as fuel the nutrients of the food tend to protect each other and the materials of the body from being consumed.

The bodily machine is made of protein. That is to say, blood, muscle, tendon, bone, and brain, all consist of, or at least contain, protein compounds. These are formed from the myosin of meat and fish, the casein of milk, the albumen of eggs, the gluten of wheat and other compounds. As the muscle and other tissues are used up in bodily activity, the same materials of the food are used for their repair. Of course, the mineral matters have a good deal to do with the building up of the tissues. Thus, phosphate of lime is an essential ingredient of the bones.

But the machine needs fuel. The starch of the bread and the potatoes we eat and the sugar put in our coffee, are burned in the body and yield heat and power, just as truly as does the coal which is burned in a stove to heat the house, or under a boiler to drive an engine. The fats serve the same purpose, only they are a more concentrated fuel than the carbohydrates. The body transforms the carbohydrates into fat, which it keeps as a reserve of fuel in the most concentrated form.

But the protein compounds can also serve as fuel. A dog can live on lean meat. We can likewise use the protein of our bodies to supply us with heat and muscular strength. The animal machine differs from others in that it can use its own substance for fuel.

The different food ingredients can, to a greater or less extent, do one another's work. If the body has not enough of one for fuel it can use another. But while the protein can be consumed for fuel in the place of fats or carbohydrates, neither of the latter can take the place of protein in building and repairing the tissues of the body.

THE POTENTIAL ENERGY OF FOOD.

Heat and muscular power, like mechanical power, light, and electricity, are forms of energy. The energy is latent in the food, and is developed as the food is consumed in the body. We call it potential energy, and measure its quantity as we measure quantities of heat or of mechanical power. In other words, the value of food for fuel is expressed in terms of potential energy. The quantities of potential energy in food materials are determined by experiments with an apparatus called the calorimeter. The unit commonly used is the Calorie*, the amount of heat which would raise the temperature of a kilogram of water one degree centigrade (or a pound of water four degrees Fahrenheit). Instead of this unit of heat we may use a unit of mechanical energy, for instance the foot-ton, which is the force that would lift one ton one foot. One Calorie corresponds very nearly to 1.53 foot-tons.

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* The same word calorie, but spelled with a small c, is used to designate the heat required to raise the temperature of a gram of water a degree. One Calorie is thus equal to 1,000 calories.

Taking ordinary food materials as they come, the following general estimate has been made* for the average amount of energy in one gram of each of the classes of nutrients.

POTENTIAL ENERGY IN NUTRIENTS OF FOOD.

	CALORIES.	FOOT-TONS.
In one gram of protein, - - - - - -	4.1	6.3
In one gram of fats, - - - - - - -	9.3	14.2
In one gram of carbohydrates, - - - -	4.1	6.3

These figures mean that when a gram of fat, be it the fat of food or body-fat, is consumed in the body, it will, if its potential energy be all transformed into heat, yield enough to warm nine and three-tenths kilograms of water one degree of the centigrade thermometer, (or four pounds of water one degree Fahrenheit), or, if it be transformed into mechanical energy, such as the steam-engine or the muscles use to do their work, it will furnish as much as would raise one ton fourteen and two-tenths feet, or fourteen and two-tenths tons one foot. A gram of protein or carbohydrates would yield a little less than half as much energy as a gram of fat.

It must be remembered that we are to-day only at the beginning of our knowledge of these subjects, and a very large amount of the most laborious, painstaking, and abstract inquiry will be needed to tell satisfactorily what needs to be known. But we are doubtless warranted in using these figures with the distinct understanding that they are subject to such revision as future research shall indicate.

In other words, when we compare the nutrients in respect to their fuel values, their capacities for yielding heat and mechanical power, an ounce of protein of lean meat or albumen of egg is just about equivalent to an ounce of sugar or starch; and a little over two ounces of either would be required to equal an ounce of the fat of meat or butter or the body-fat. The potential energy in the ounce of protein or carbohydrates would, if transformed into heat, suffice to raise the temperature of one hundred and thirteen pounds of water one degree Fahrenheit, while an ounce of fat, if completely burned in the body or in the calorimeter, would yield as much heat as would warm over twice that weight of water one degree.

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* By Prof. Rubner. Zeitschrift fur Biologie, 19,313. These estimates are tentative. Doubtless future research will alter them more or less.

What has been said above about the ways in which our food nourishes us may be briefly summarized as follows:

WAYS IN WHICH FOOD IS USED IN THE BODY.

Food supplies the wants of the body in several ways. It either:

1. Is used to form the tissues and fluids of the body;
2. Is used to repair the wastes of tissues;
3. Is stored in the body for future consumption;
4. Is consumed as fuel, its potential energy being transformed into heat or muscular energy or other forms of energy required by the body; or,
5. In being consumed protects tissues or other food from consumption.

Uses of the Different Classes of Nutrients.

Protein forms tissue (muscle, tendon, etc., and fat) and serves as fuel.	All yield energy in form of heat and muscular strength.
Fats form fatty tissue (not muscle, etc.,) and serve as fuel.	
Carbohydrates are transformed into fat and serve as fuel.	

In being themselves burned to yield energy, the nutrients protect each other from being consumed. The protein and fats of body-tissue are used like those of food. An important use of the carbohydrates and fats is to protect protein (muscle, etc.), from consumption.

Table 60, showing the composition of specimens of some of our more common animal and vegetable foods, follows on pages 170, 171. The last column gives the number of Calories in one pound of each food material. These are estimated from the proportions of nutrients as indicated in the table.*

The first part of the table gives the chemical composition, including both edible portion and refuse. It is interesting to note the difference in the amounts of refuse and edible portion in the different kinds of meats, fish, etc., as they are ordinarily found in

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* The figures for potential energy are calculated for each food material by multiplying the number of grams of protein and of carbohydrates in one pound (1 lb. equals 453.6 grams) by 4.1, and the number of grams of fat by 9.3, and taking the sum of these three products as the number of Calories of potential energy in a pound of the material.

TABLE 60.

Percentages of Nutrients (Nutritive Ingredients), Water, and Refuse, and Estimated Potential Energy (Fuel Value) in Specimens of Food Materials.

FOOD MATERIALS.	Refuse (Bones, Skin, Shell, etc.)	EDIBLE PORTION.						
			NUTRIENTS.					
		Water.	Total.	Protein.	Fat.	Carbohydrates.	Mineral Matters.	Potential Energy in one Pound.
Animal Foods, as Purchased.	%	%	%	%	%	%	%	Cal.
Beef—Neck.	20.0	49.6	30.4	15.6	14.0	—	0.8	880
Shoulder,	12.6	55.8	31.6	17.0	13.7	—	0.9	895
Chuck rib,	14.6	49.5	35.9	15.0	20.1	—	0.8	1125
Rib,	21.0	38.2	40.8	12.2	27.9	—	0.7	1405
Sirloin,	19.5	48.3	32.2	15.0	16.4	—	0.8	970
Round steak,	7.8	60.9	31.3	18.0	12.3	—	1.0	855
Side, without kidney fat,	19.2	44.3	36.5	13.9	21.8	—	0.8	1180
Rump, corned,	5.0	70.8	24.2	16.7	5.1	—	2.4	525
Flank, corned,	12.1	43.7	44.2	12.4	29.2	—	2.6	1460
Veal—Shoulder,	17.9	56.7	25.4	16.6	7.9	—	0.9	640
Mutton—Shoulder,	16.3	49.0	34.7	15.1	18.8	—	0.8	1075
Leg,	18.1	50.6	31.3	15.0	15.6	—	0.7	935
Loin,	15.8	41.5	42.7	12.6	29.5	—	0.6	1480
Side, without kidney fat,	17.3	44.2	38.5	14.0	23.7	—	0.8	1260
Pork—Shoulder roast, fresh,	14.6	43.0	42.4	13.6	28.0	—	0.8	1435
Ham, salted, smoked,	11.4	36.8	51.8	14.8	34.6	—	2.4	1735
Chicken,	38.2	44.6	17.2	15.1	1.2	—	0.9	330
Turkey,	32.4	44.7	22.9	16.1	5.9	—	0.9	550
Eggs, in shell,	13.7	63.1	23.2	12.1	10.2	—	0.9	655
Fish, etc..—Flounder, whole,	66.8	27.2	6.0	5.2	0.3	—	0.5	110
Bluefish, dressed,	48.6	43.0	11.1	9.8	0.6	—	0.7	210
Codfish, dressed,	29.9	58.5	11.6	10.6	0.2	—	0.8	205
Shad, whole,	50.1	35.2	14.7	9.2	4.8	—	0.7	375
Mackerel, whole,	44.8	40.4	15.0	10.0	4.3	—	0.7	365
Halibut, dressed,	17.7	61.9	20.4	15.1	4.4	—	0.9	465
Salmon, whole,	35.3	40.6	24.1	14.3	8.8	—	1.0	635
Salt codfish,	42.1	40.5	17.6	16.0	0.4	—	1.2	315
Smoked herring,	50.9	19.2	29.9	20.2	8.8	—	0.9	745
Salt mackerel,	40.4	28.1	31.5	14.7	15.1	—	1.7	910
Canned salmon,	4.9	59.3	35.8	19.3	15.3	—	1.2	1005
Lobsters,	62.1	31.0	6.9	5.5	0.7	0.1	0.6	135
Oysters,	82.3	15.4	2.3	1.1	0.2	0.6	0.4	40
Animal Foods, Edible Portion.								
Beef—Neck,	—	62.0	38.0	19.5	17.5	—	1.0	1100
Shoulder,	—	63.9	36.1	19.5	15.6	—	1.0	1020
Chuck rib,	—	58.0	42.0	17.6	23.5	—	0.9	1320
Rib,	—	48.1	51.9	15.4	35.6	—	0.9	1790
Sirloin,	—	60.0	40.0	18.5	20.5	—	1.0	1210
Round,	—	68.2	31.8	20.5	10.1	—	1.2	805
Side, without kidney fat,	—	54.8	45.2	17.2	27.1	—	0.9	1465
Rump, corned,	—	58.1	41.9	13.3	26.6	—	2.0	1370
Flank, corned,	—	49.8	50.2	14.2	33.0	—	3.0	1655
Veal—Shoulder,	—	68.8	31.2	20.2	9.8	—	1.2	790
Mutton—Shoulder,	—	58.6	41.4	18.1	22.4	—	0.9	1280
Leg,	—	61.8	38.2	18.3	19.0	—	0.9	1140
Loin,	—	49.3	50.7	15.0	35.0	—	0.7	1755

TABLE 60.—*(Continued.)*

FOOD MATERIALS.	Refuse (Bones, Skin, Shell, etc.)	EDIBLE PORTION.						
			NUTRIENTS.					
		Water.	Total.	Protein.	Fat.	Carbo-hydrates.	Mineral Matters.	Pot'nl En'gy in one Pound.
Animal Foods, Edible Portion.	%	%	%	%	%	%	%	Cal.
Mutton–Side, without kidney fat	—	53.5	46.5	16.9	28.7	—	0.9	1525
Pork—Shoulder roast, fresh,	—	50.3	49.7	16.0	32.8	—	0.9	1680
Ham, salted, smoked,	—	41.5	58.5	16.7	39.1	—	2.7	1960
Fat, salted,	—	12.1	87.9	0.9	82.8	—	4.2	3510
Sausage—Pork,	—	41.2	58.8	13.8	42.8	—	2.2	2065
Bologna,	—	62.4	37.6	18.8	15.8	—	3.0	1015
Chicken,	—	72.2	27.8	24.4	2.0	—	1.4	540
Turkey,	—	66.2	33.8	23.9	8.7	—	1.2	810
Eggs,	—	73.8	26.2	14.9	10.5	—	0.8	721
Milk,	—	87.0	13.0	3.6	4.0	4.7	0.7	325
Butter,	—	10.5	89.0	1.0	85.0	0.5	3.0	3615
Oleomargarine,	—	11.0	89.5	0.6	85.0	0.4	3.0	3605
Cheese—Full cream,	—	30.2	69.8	28.3	35.5	1.8	4.2	2070
Skim-milk,	—	41.3	58.7	38.4	6.8	8.9	4.6	1165
Fish—Flounder,	—	84.2	15.8	13.8	0.7	—	1.3	285
Haddock,	—	81.7	18.3	16.8	0.3	—	1.2	325
Codfish,	—	82.6	17.4	15.8	0.4	—	1.2	310
Shad,	—	70.6	29.4	18.6	9.5	—	1.3	745
Mackerel,	—	73.4	26.6	18.2	7.1	—	1.3	640
Halibut,	—	75.4	24.6	18.3	5.2	—	1.1	560
Salmon,	—	63.6	36.4	21.6	13.4	—	1.4	965
Salt cod,	—	53.6	—	21.4	0.3	—	1.6	410
Herring, salt,	—	34.6	—	36.4	15.8	—	1.5	1345
Mackerel, salt,	—	43.4	—	17.3	26.4	—	2.6	1860
Oysters,	—	87.1	12.9	6.0	1.2	3.7	2.0	230
Vegetable Foods.								
Wheat flour,	—	12.5	87.5	11.0	1.1	74.9	0.5	1644
Graham flour (wheat),	—	13.1	86.9	11.7	1.7	71.7	1.8	1625
Rye flour,	—	13.1	86.9	6.7	0.8	78.7	0.7	1625
Buckwheat flour,	—	14.6	85.4	6.9	1.4	76.1	1.0	1605
Oatmeal,	—	7.6	92.4	15.1	7.1	68.2	2.0	1850
Cornmeal,	—	15.0	85.0	9.2	3.8	70.6	1.4	1645
Rice,	—	12.4	87.6	7.4	0.4	79.4	0.4	1630
Peas,	—	12.3	87.7	26.7	1.7	56.4	2.9	1565
Beans,	—	12.6	87.4	23.1	2.0	59.2	3.1	1615
Potatoes,	—	78.9	21.1	2.1	0.1	17.9	1.0	375
Sweet potatoes,	—	71.1	28.9	1.5	0.4	26.0	1.0	530
Turnips,	—	89.4	10.6	1.2	0.2	8.2	1.0	185
Carrots,	—	88.6	11.4	1.1	0.4	8.9	1.0	200
Onions,	—	87.6	12.4	1.4	0.3	10.1	0.6	225
String beans,	—	87.2	12.8	2.2	0.4	9.4	0.8	235
Green peas,	—	78.1	21.9	4.4	0.6	16.0	0.9	405
Green corn,	—	81.3	18.7	2.8	1.1	13.2	0.6	345
Tomatoes,	—	96.0	4.0	0.8	0.4	2.5	0.3	80
Cabbage,	—	91.9	8.1	2.1	0.3	5.5	1.1	155
Apples,	—	83.2	16.8	0.2	0.4	15.9	0.3	315
Sugar, granulated,	—	2.0	98.0	—	—	97.8	0.2	1820
Molasses,	—	24.6	75.4	—	—	73.1	2.3	1360
White bread (wheat),	—	32.3	67.7	8.8	1.7	56.3	0.9	1280
Boston crackers,	—	8.3	91.7	10.7	9.9	68.7	2.4	1895

the markets. In some specimens of meats, as round steak, the bone and other inedible portions are less than one-tenth of the whole, whereas in the flounder the refuse amounts to two-thirds and the edible portion to only one-third of the whole.

In the part of the table which gives the percentages of nutrients in the edible portion of foods, it is interesting to note the wide variations in the proportions of water and of nutrients. In general, the animal substances contain the most water and the vegetable foods the most nutrients, though potatoes and turnips and allied green vegetables are exceptions. Meats have more water in proportion as they have less fats. Thus, very lean beef is nearly three-fourths water, while other and fatter cuts are less than one-half water. The flesh of fish is in general more watery than that of ordinary meats. Flour and meal have very little water, and sugar almost none. In examining the proportions of individual nutrients, the most striking fact is the difference between the meats and the fish, on one hand, and the vegetable foods on the other hand. The vegetable foods are rich in carbohydrates, and the meats abound in protein and fats, of which the vegetable foods usually have but little. Beans and oatmeal, however, are rich in protein, while fat pork has very little.

It must be borne in mind, however, that different specimens of the same kind of material may differ widely in composition, especially in the case of meats, and that the figures here given are based upon the comparatively few analyses now available. Many more analyses will be needed to show the ranges of variation and the actual averages.

ACTUAL DIETARIES OF DIFFERENT CLASSES OF PEOPLE.

Table 61* gives the quantities of nutrients and potential energy in a number of observed dietaries. The figures for European dietaries are mostly by Voit and his followers in Germany, and by Playfair in England. The American figures are by the writer and his associates; those for the army and navy rations are based upon the United States Regulations, the rest upon observations of actual dietaries.

As the subject was discussed at some length in the Report of the Station for 1891 (pp. 106–159), and it is the purpose to recur to it later, the citing of the figures will suffice here. The dietary standards indicate the amounts assumed to be appropriate for nourishment on the average, and are subject to revision.

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* Quoted from Experiment Station Record, Vol. III., p. 673.

American and European Dietaries and Dietary Standards.

TABLE 61.

[Quantities per man per day.]

DIETARIES.	Nutrients.			Potential Energy.	Nutritive Ratio.
	Protein.	Fats.	Carbohydrates.		
American (Massachusetts and Connecticut.)	gm.	gm	gm.	Cal.	1:
Family of glass blowers in East Cambridge, Mass., -	95	132	481	3,590	8.2
Boarding house, Lowell, Mass.; boarders, operatives in cotton mills, - - - - - - - - -	132	200	549	4,650	7.6
Boarding house, Middletown, Conn.; well-paid machinists, etc., at moderate work, - - - - - Food purchased	126	188	426	4,010	6.8
Food eaten, -	103	152	402	3,490	7.3
Blacksmiths, Lowell, at hard work, - - - - -	200	304	795	6,905	7.4
Brickmakers, Mass.; 237 persons at very severe work, -	180	365	1150	8,850	11.0
Mechanics, etc., in Massachusetts and Connecticut; average of 4 dietaries of mechanics at severe work (not including No. 5), - - - - - - -	215	296	749	6,705	6.6
Average of 20 dietaries of wage-workers in Massachusetts and Connecticut, - - - - - - -	152	225	625	5,275	7.5
Average of 5 dietaries of professional men and college students in Middletown, Conn., - - - - - Food purchased	133	163	508	4,140	6.6
Food eaten, -	126	152	489	3,925	6.6
European (English, German, Danish, and Swedish.)					
Well-fed tailors, England, Playfair, - - - - -	131	39	525	3,055	4.7
Hard-worked weavers, England, Playfair, - - -	151	43	622	3,570	4.8
Blacksmiths at active labor, England, Playfair, - -	176	71	667	4,115	4.7
Mechanic, Munich, 60 years old, in comfortable circumstances, light work, Forster, - - - - -	117	68	345	2,525	4.3
Well-paid mechanics, Munich, Voit, - - - - -	151	54	479	3,085	4.0
Carpenters, coopers, locksmiths, Bavaria; average of 11 dietaries, - - - - - - - - - -	122	34	570	3,150	5.3
Miners at severe work, Prussia, Steinheil, - - -	133	113	634	4,195	6.7
Brickmakers (Italians), Munich, diet mainly maize meal and cheese, severe work, - - - - -	167	117	675	4,540	5.6
German army ration, peace footing, - - - - -	114	39	480	2,800	5.0
German army ordinary ration, war footing, - -	134	58	489	3,095	4.6
German army extraordinary ration, in war, - -	192	45	678	3,985	4.1
University professor, Munich; very little exercise, -	100	100	240	2,325	4.7
Lawyer, Munich, Forster, - - - - - - - -	80	125	222	2,400	6.3
Physician, Munich, Forster, - - - - - - -	127	89	362	2,830	4.4
Physician, Copenhagen, Jürgeson, - - - - -	135	140	239	2,835	4.1
Average of 7 dietaries of professional men and students,	114	111	285	2,670	4.7
Dietary Standards.					
Adult in full health, Playfair, - - - - - -	119	51	531	3,140	5.5
Active laborers, Playfair, - - - - - - - -	156	71	568	3,630	4.7
Man at moderate work, Moleschott, - - - - -	130	40	550	3,160	4.9
Man at moderate work, Wolff, - - - - - -	125	35	540	3,030	4.9
Man at moderate work, Voit, - - - - - -	118	56	500	3,055	5.3
Man at hard work, Voit, - - - - - - - -	145	100	450	3,370	4.7
Man with moderate muscular work, writer, - -	125	125	450	3,520	5.9
Man with active muscular work, writer, - - -	150	150	500	4,060	5.6
Man at severe muscular work, writer, - - -	175	250	650	5,705	6.9
Man at very severe muscular work, writer, - -	200	350	800	7,355	7.9

THE DIGESTIBILITY OF FOOD.

"We live upon not what we eat, but what we digest." In other words, the value of food for nutriment depends not only on how much of nutrients it contains, but also upon how much of these the body digests and uses for its support.

By digestibility of food several different things are, or may be, meant. Some of these, as the ease with which a given food-material is digested, the time required for the process, the influence of different substances and conditions on digestion, and the effects upon health and comfort are so dependent upon the peculiarities of different individuals, and are so difficult of measurement as to make the laying down of hard-and-fast rules impossible. For our present purpose, the most important factor is the amount digested. This, fortunately, is more easy to determine. Understanding by the digestibility of a food the proportions of each of the nutrients which can be actually digested by healthy persons, the question becomes simpler and can be answered more or less accurately by experiment.

One outcome of the careful experimenting of the last few years is the proof that there is not the difference in the amounts digested from the same kind of food material by different persons or by the same person under different circumstances, that has been popularly supposed.

The percentages of the more important constituents of various foods actually digested by domestic animals of different kinds, horses, oxen, cows, sheep, swine, etc., have been a matter of active experimental investigation in the experiment stations in Europe for the last thirty years. Of late a number of American stations have been engaged in similar inquiries. Briefly expressed, the method consists in weighing and analyzing both the food consumed and the solid excrement. Since the latter represents the amount of food undigested and unassimilated, the difference is taken as the amount digested.

Such experiments are more difficult with human subjects than with domestic animals, because men are accustomed to more varied diet. To make an experiment on the digestibility of a given food most accurate it should be eaten by itself. An ox will thrive comfortably for a long time on a single kind of fodder, as hay, but most men are used to a mixed diet, and it is not easy to continue to eat the same kind of food long enough for a satisfactory trial; and there is, furthermore, the danger that the accuracy of the experiment may be impaired through derangement of the digestive organs by the long restriction to one kind of food. The number of experiments upon the digestibility of food of man is small. Scarcely more than a hundred reliable series have been reported. The very large majority of them have been made in Germany, most of them with healthy men. In table 62 herewith, which, like the others in this article, has been prepared with the aid of Mr. C. D. Woods, the attempt is made to epitomize the results of the majority of these experiments. The figures for the animal foods are probably not far from correct. Of the figures for the vegetable foods, those for the protein are nearly accurate, the percentage assumed for the carbohydrates is doubtless not far out of the way, that for the fats is the least reliable. The numbers in the table which thus represent the proportions of the several kinds of nutrients that are actually digested are called co-efficients of digestibility.

TABLE 62.

Digestibility of Nutrients of Food Materials.

ANIMAL FOODS.	PERCENTAGES DIGESTED.			VEGETABLE FOODS.	PERCENTAGES DIGESTED.		
	Protein.	Fat.	Carbo-hydrates.		Protein.	Fat.	Carbo-hydrates.
	%	%	%		%	%	%
Beef and veal,	100	95	—	Wheat flour, fine,	85	80 % assumed for all.	95 % assumed for all.
Mutton,	100	95	—	Wheat flour, medium,	81		
Pork,	100	95	—	Wheat flour, coarse,	75		
Fish and oysters,	100	95	—	Rice,	85		
Milk,	100	96	100	Macaroni,	85		
Cheese,	100	95	100	Rye flour,	78		
Butter,	—	96	—	Maize meal,	85		
Oleomargarine,	—	95	—	Potatoes,	75		
Tallow,	—	95	—	Cabbages, turnips, etc.,	80		
Lard,	—	95	—	Beans,	85		
Oils,	—	95	—	Peas,	85		
Eggs,	100	98	—				

Table 63 exhibits, for a number of food materials, the proportions of nutrients which are estimated to be digestible. It was computed by applying the figures in table 62 to the figures for composition of food materials in table 60 above. Thus, in beef the whole of the protein (100 per cent. in table 62) is assumed to be digestible. The average of the analyses of shoulder of beef, epitomized in table 60, gives 19.5 per cent. of protein. This is, accordingly, the percentage assumed to be digestible. In wheat flour 85 per cent. of the total protein is estimated to be digestible, the remainder, 15 per cent., being undigestible. The wheat flour of table 60 contains 11 per cent. of protein Accordingly 9.4 per cent. will be digestible and 1.6 per cent. undigestible.

TABLE 63.

Estimates of Proportions of Digestible and Undigestible Nutrients in Food Materials.

FOOD MATERIALS.	PROTEIN.			FATS.			CARBO-HYDRATES.		
	Digested.	Undigested.	Total.	Digested.	Undigested.	Total.	Digested.	Undigested.	Total.
	%	%	%	%	%	%	%	%	%
Beef, shoulder,	19.5	—	19.5	14.8	.8	15.6	—	—	—
Beef, sirloin,	18.5	—	18.5	19.5	1.0	20.5	—	—	—
Beef, round,	20.5	—	20.5	9.6	.5	10.1	—	—	—
Veal, shoulder,	20.2	—	20.2	9.3	.5	9.8	—	—	—
Mutton, shoulder,	18.1	—	18.1	21.3	1.1	22.4	—	—	—
Mutton, loin,	15.0	—	15.0	33.3	1.7	35.0	—	—	—
Pork, shoulder,	16.0	—	16.0	31.2	1.6	32.8	—	—	—
Pork, very fat,	.9	—	.9	78.7	4.1	82.8	—	—	—
Eggs,	14.9	—	14.9	10.3	.2	10.5	—	—	—
Milk,	3.6	—	3.6	3.8	.2	4.0	4.7	—	4.7
Butter,	?	?	1.0	81.6	3.4	85.0	.5	—	.5
Cheese, full cream,	28.3	—	28.3	33.7	1.8	35.5	1.8	—	1.8
Cheese, skim milk,	38.4	—	38.4	6.5	.3	6.8	8.9	—	8.9
Haddock,	16.8	—	16.8	.3	—	.3	—	—	—
Bluefish,	19.0	—	19.0	1.1	.1	1.2	—	—	—
Cod,	15.8	—	15.8	.4	—	.4	—	—	—
Shad,	18.6	—	18.6	9.0	.5	9.5	—	—	—
Mackerel,	18.8	—	18.8	7.8	.4	8.2	—	—	—
Halibut,	18.3	—	18.3	4.9	.3	5.2	—	—	—
Salmon,	21.6	—	21.6	12.7	.7	13.4	—	—	—
Wheat flour, fine,	9.4	1.6	11.0	.9	.2	1.1	71.1	3.8	74.9
Wheat flour, medium,	9.5	2.2	11.7	1.4	.3	1.7	68.1	3.6	71.7
Cracked wheat,	8.9	3.0	11.9	1.4	.3	1.7	70.9	3.7	74.6
Maize meal,	7.8	1.4	9.2	3.0	.8	3.8	67.1	3.5	70.6
Rice,	6.3	1.1	7.4	.3	.1	.4	75.4	4.0	79.4
Potatoes,	1.6	.5	2.1	?	?	0.1	17.0	.9	17.9
Turnips,	1.0	.2	1.2	?	?	0.2	7.8	.4	8.2
Beets,	1.2	.3	1.5	?	?	0.1	8.5	.4	8.9
Wheat bread,	7.1	1.7	8.8	1.4	.3	1.7	53.4	2.8	56.2
Rye bread,	6.5	1.9	8.4	.4	.1	0.5	56.7	3.0	59.7
Graham bread,	7.1	2.4	9.5	1.1	.3	1.4	50.6	2.7	53.3

The results of experimental inquiry regarding the quantities of nutrients digested from reasonable amounts of ordinary food materials by healthy people may be briefly summarized as follows:

1. The protein of our ordinary meats, fish, and milk is very readily and completely digested. The protein of vegetable foods is much less completely digested than that of animal foods. Of that of potatoes and beans, for instance, a third or more may escape digestion, and thus be useless for nourishment.

2. Much of the fats of animal food may at times fail of digestion. This is presumably true of vegetable fats, but the quantities are in general so small that the determinations of the proportions digested are not very accurate.

3. The carbohydrates, which make up a large part of vegetable food, are in general very digestible. The crude fiber or cellulose is an exception, but the quantities of this in the materials used for the food of man are too small to be of importance. Sugar is believed to be completely digested. This is assumed to be the case with the sugar of milk. The other carbohydrates of animal foods are very small in amount.

4. The animal foods have in general the advantage of the vegetable foods in digestibility, that they contain more protein and that their protein is more digestible.

5. The quantity digested appears to be less affected by flavor, flavoring materials and food adjuncts and to differ less with different persons, than is commonly supposed.

PECUNIARY ECONOMY OF FOOD.

The cost of food is the principal item of the living expenses of the majority of people, of all, indeed, but the especially well-to-do in Connecticut and the other Eastern States.* In the Report of the Bureau of Statistics of Labor of Massachusetts for 1884 are summarized the results of investigations into the cost of living of people with different incomes in Massachusetts, in Great Britain, and in Germany. Dividing expenses into those for food, clothing, rent, fuel, and sundries, the percentage of the whole income expended for food averages as follows:

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*In portions of the West and South, where food is less expensive, its cost is somewhat less in comparison with other living expenses.

Percentage of Family Income Expended for Subsistence.

	ANNUAL INCOME.	PER CENT. EXPENDED FOR FOOD.
Germany.		
Workingmen,	$225 to $300	62
Intermediate class,	450 to 600	55
In easy circumstances,	750 to 1100	50
Great Britain.		
Workingmen,	$500	51
Massachusetts.		
Workingmen,	$350 to $400	64
Workingmen,	450 to 600	63
Workingmen,	600 to 750	60
Workingmen,	750 to 1200	56
Workingmen,	Above 1200	51

The large majority of families in this country are said to have not over $500 a year to live upon. More than half of this goes, and must go, for food. The cost of preparing food for the table, rent, clothing, and all other expenses must be provided from the remainder.

These statements apply less accurately to farmers than to the inhabitants of the larger towns, but, although the farmer produces much of his food, yet taking everything into account the expense for nutriment is large even for him.

Although the cost of food makes so large a part of the whole cost of living, and although the health and strength of all are so intimately connected with and dependent upon their diet, yet even the most intelligent people know less of the actual uses and values of their food for fulfilling its purposes than of almost any other of the necessities of life.

Cheap vs. Dear Food.—The cheapest food is that which supplies the most nutriment for the least money. The most economical food is that which is the cheapest and at the same time best adapted to the wants of the user. The maxim that "the best is the cheapest" does not apply to food. The best food in the sense of that which is the finest in appearance and flavor, and which is sold at the highest price, is not generally the cheapest, nor is it always the most healthful or economical.

There seems to be among the people of this country an idea that there is some mysterious virtue in those kinds of foods that have the most delicate appearance and flavor, and which command the highest price. The notion is current that whatever else one has or does not have, he must, if possible, have this sort of food, and that to economize by using anything inferior in quality or cheaper in price would be a sacrifice of both dignity and principle.

Mr. Lee Meriwether, who has given much attention to this especial subject, cites a case in point, that of a coal laborer who boasted: "No one can say that I do not give my family the best of flour, the finest of sugar, the very best quality of meat." He paid $156 a year for the nicest cuts of meat, which his wife had to cook before six in the morning or after half past six at night, because she worked all day in a factory. When excellent butter was selling at 25 cents a pound he paid 29 cents for an extra quality. He spent only $108 a year for clothing for his family of nine, and only $72 a year for rent in a close tenement house, where they slept in rooms without windows or closets. He indulged in this extravagance in food when much less expensive food materials, such as regularly come upon the tables of men of wealth, would have been just as nutritious, just as wholesome, and in every way just as good, save in its gratification to pride and palate. He was committing an immense economic blunder. Like thousands of others, he did so without understanding at all that it was a blunder.

Just here is one great difficulty: the lack of information regarding the nutritive values of foods. Even those who wish and try to economize in their purchase and use of food do not understand how. They carefully consult the prices, but have in general very vague ideas about values for nourishment as compared with cost. Persons who are exceedingly economical in purchase of clothing, and in other expenditures, do not, and in many instances cannot practice intelligently the same economy at the markets. Frequently people pay from one to two dollars a pound for the protein of the meat and other animal foods they use, when it might be obtained in forms equally wholesome and nutritious for 15 to 50 cents per pound. The food thus purchased is apt to supply some of the nutrients in excessive amounts as well as at needlessly high costs, while it furnishes others in insufficient quantities or in unfitting forms and in uneconomical ways, and only too often a large part of it finds its way into the drain or the garbage barrel instead of being utilized for nourishment. The difficulty is that in comparing different food materials with respect to their cheapness or dearness, we are apt to judge them by the prices per pound, quart or bushel, without much regard to the amounts or kinds of actual nutrients which they contain.

Of the different food materials which the market affords, and which are palatable, nutritious, and otherwise fit for nourishment, what ones are peculiarly the most economical? There are various ways of comparing food materials with respect to the relative cheapness or dearness of their nutritive ingredients. One, and perhaps the best, consists in comparing the nutrients obtained for a given sum in different materials. Table 64, which follows, gives estimates of amounts of nutrients that could be purchased for twenty-five cents at the rates named. The calculations are based upon the analyses in table 60, and upon the retail prices current in Connecticut.

The figures of the table tell their story so plainly that they need very little comment. A quarter of a dollar invested in the sirloin of beef at 22 cents per pound pays for one and one-seventh pounds of the meat with three-eighths of a pound of actually nutritive material. This would contain one-sixth of a pound of protein and one-fifth of a pound of fat, and supply 1,120 Calories of energy. The same amount of money paid for oysters at the rate of 50 cents per quart, brings two ounces of actual nutrients, an ounce of protein and 230 Calories of energy. But in buying wheat flour at seven dollars a barrel, the 25 cents pay for six and a quarter pounds of nutrients with eight-tenths of a pound of protein and 11,755 Calories of energy.

The price of food is not regulated solely by its value for nutriment. Its agreeableness to the palate or to the buyer's fancy makes a large factor of the current demand and market price. There is no more nutriment in an ounce of protein or fat of the tenderloin of beef than in that of the round or shoulder. The protein of animal foods does, however, have an advantage over that of vegetable foods. Animal foods, such as meats, fish, milk and the like, gratify the palate in ways which most vegetable foods do not, and, what is perhaps of still greater weight in regulating the actual usage of communities by whose demand the prices are regulated, they satisfy a real need by supplying protein and fats, which vegetable foods lack.

Table 64.

Amounts of Nutrients furnished for Twenty-five Cents in Food Materials at Ordinary Prices.

Food Materials as Furnished.	Prices per Pound.	TWENTY-FIVE CENTS WILL PAY FOR					
		Total Food Materials.	Nutrients.				Calories of Potential Energy.
			Total.	Protein.	Fats.	Carbo-hydrates.	
Meats, Etc.	Cts.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cals.
Beef, neck,	8	3.13	.95	.49	.44	—	2765
	6	4.17	1.27	.65	.58	—	3655
Chuck ribs,	16	1.56	.56	.23	.31	—	1735
	12	2.08	.75	.31	.42	—	2350
Ribs,	22	1.14	.47	.14	.32	—	1610
	18	1.39	.57	.17	.39	—	1960
Shoulder,	14	1.79	.57	.30	.25	—	1615
	10	2.50	.79	.43	.34	—	2235
Sirloin,	22	1.14	.37	.17	.19	—	1120
	18	1.39	.45	.21	.23	—	1360
Rump,	18	1.39	.63	.19	.43	—	2170
	15	1.67	.76	.23	.52	—	2620
Round, first cut,	18	1.39	.44	.25	.17	—	1180
	15	1.67	.52	.30	.21	—	1445
Round, second cut,	10	2.50	.52	.35	.15	—	1285
	8	3.13	.65	.44	.18	—	1580
Flank, corned,	15	1.67	.77	.21	.49	—	2460
	10	2.50	1.11	.31	.73	—	3655
Corned and canned,	18	1.39	.66	.37	.24	—	1700
	14	1.79	.85	.48	.31	—	2200
Liver,	8	3.13	.96	.63	.17	.11	2095
Mutton, shoulder,	20	1.25	.41	.18	.22	—	1265
	15	1.67	.58	.25	.31	—	1775
Leg,	25	1.00	.31	.15	.16	—	955
	20	1.25	.39	.19	.20	—	1195
Loin,	25	1.00	.43	.13	.29	—	1465
	20	1.25	.53	.15	.37	—	1840
Pork, rib roast,	12	2.08	.88	.28	.58	—	2970
	16	2.50	1.06	.34	.70	—	5885
Smoked ham, whole,	16	1.56	.86	.25	.58	—	2915
	12	2.08	1.08	.31	.72	—	3615
Salt, fat pork,	15	1.67	1.17	.02	1.38	—	5860
	12	2.08	1.03	.02	1.72	—	7295
Pork sausage,	15	1.67	.98	.23	.72	—	3465
	12	2.08	1.22	.29	.89	—	4295
Poultry, etc., chicken,	22	1.14	.32	.28	.02	—	605
	16	1.56	.45	.38	.03	—	835
Turkey,	23	1.09	.37	.26	.09	—	865
	18	1.38	.47	.32	.12	—	1100

TABLE 64.—*(Continued.)*

FOOD MATERIALS AS FURNISHED.	Prices per Pound.	TWENTY-FIVE CENTS WILL PAY FOR					
		Total Food Materials.	Nutrients.				Calories of Potential Energy.
			Total.	Protein.	Fats.	Carbo-hydrates.	
Fish, Etc.	Cents.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cals.
Shad, whole,	15	1.67	.25	.15	.09	—	660
	10	2.50	.37	.23	.12	—	935
Mackerel, whole,	18	1.39	.22	.14	.06	—	515
	15	1.67	.25	.17	.07	—	610
	10	2.50	.37	.25	.11	—	930
Blue fish, dressed,	15	1.67	.19	.16	.01	—	340
	10	2.50	.28	.25	.02	—	550
Striped bass, whole,	18	1.39	.14	.12	.01	—	265
	12	2.08	.21	.17	.02	—	400
Haddock, dressed,	8	3.13	.28	.26	.01	—	525
	5	5.00	.45	.41	.01	—	805
Cod, dressed,	10	2.50	.28	.25	.01	—	505
	8	3.13	.36	.33	.01	—	655
	6	4.17	.48	.44	.01	—	860
Halibut, steaks,	20	1.25	.26	.19	.06	—	605
	16	1.56	.32	.24	.07	—	740
Salt cod,	8	3.13	.55	.50	.01	—	970
	5	5.00	.88	.80	.02	—	1570
Salt mackerel,	16	1.56	.49	.23	.24	—	1440
	12	2.08	.66	.31	.32	—	1925
Canned salmon,	20	1.25	.46	.25	.20	—	1310
Oysters, 50c. per quart,	25	1.00	.13	.06	.01	.04	230
Oysters, 35c. per quart,	17.5	1.43	.18	.09	.02	.05	345
Lobster, whole,	12	2.08	.14	.11	.01	—	345
	10	2.50	.17	.14	.02	—	345
Lobster, canned,	20	1.25	.28	.23	.01	—	470
Eggs and Dairy Products.							
Eggs, 35c. per dozen,	25	1.00	.23	.12	.10	—	645
Eggs, 25c. per dozen,	18.2	1.37	.32	.17	.14	—	910
Eggs, 15c. per dozen,	11	2.27	.53	.28	.23	—	1490
Milk, 8c. per quart,	4	6.25	.81	.23	.25	.29	2020
Milk, 6c. per quart,	3	8.33	1.08	.30	.33	.39	2675
Milk, 4c. per quart,	2	12.50	1.63	.40	.50	.59	4065
Butter,	35	.71	.64	.01	.60	—	2550
Cheese, whole milk,	30	.83	.74	.01	.71	—	3015
	25	1.00	.90	.01	.85	.01	3625
	18	1.38	.96	.40	.49	.02	2850
	15	1.67	1.17	.47	.59	.03	3420
	12	2.08	1.45	.59	.72	.04	4210

TABLE 64.—*(Continued.)*

FOOD MATERIALS AS FURNISHED.	Prices per Pound.	TWENTY-FIVE CENTS WILL PAY FOR					
		Total Food Materials.	Nutrients.				Calories of Potential Energy.
			Total.	Protein.	Fats.	Carbo-hydrates.	
Vegetable Foods.	Cents.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cals.
Potatoes, $1.00 per bushel,	1.7	14.70	.31	.03	.01	.26	580
Potatoes, .80 per bushel,	1.25	20.00	.42	.04	.02	.36	790
Potatoes, .50 per bushel,	0.85	29.40	.62	.06	.03	.53	1225
Sweet potatoes,	5	5.00	.14	.00	.00	.13	240
	3	8.33	.24	.01	.00	.22	430
Beets,	2	12.50	.14	.02	.00	.11	240
	1	25.00	.29	.04	.00	.22	485
Turnips,	2	12.50	.13	.02	.00	.10	225
	1	25.00	.27	.03	.01	.21	490
Sugar,	5	5.00	4.90	.00	.00	4.89	9095
Dried beans,	6	4.17	3.64	.96	.09	2.47	6760
	5	5.00	4.37	1.15	.10	2.96	8065
	4	6.25	5.46	1.44	.13	3.70	11110
Maize "corn" meal,	3	8.33	7.08	.77	.32	5.88	13720
	1	25.00	21.25	2.30	.95	17.65	41115
Oatmeal,	5	5.00	4.61	.74	.36	3.42	9255
Wheat flour,	4	6.25	5.47	.69	.07	4.68	10285
	3.5	7.14	6.25	.79	.08	5.35	11755
	3	8.33	7.29	.92	.09	6.24	13695
Wheat bread,	7	3.57	2.42	.31	.06	2.01	4570
	5	5.00	3.38	.44	.09	2.82	6445
Crackers,	12	2.08	1.91	.21	.20	1.47	3970
	8	3.13	2.88	.32	.29	2.21	5930
DIETARY STANDARDS.							
Man with light exercise,			1.32	.22	.22	.88	2980
Man with moderate muscular work,			1.55	.28	.28	.99	3520
Man at active muscular work,			1.76	.33	.33	1.10	4060

People who can afford it, the world over, will have animal foods and will compete with one another in the prices they give for them. In general, the animal foods are more easily and completely digested than vegetable. There is doubtless good ground for paying somewhat more for the same quantity of nutritive material in the animal food.

For persons in good health the foods in which the nutrients are most expensive are like costly articles of adornment. People who can well afford them may be justified in buying them, but they are not economical.

WASTE OF FOOD.

We waste food in two ways: We throw away a great deal and we, or at least many of us, eat more than we need. That which is thrown away in the form of kitchen and table refuse does no harm, and in so far as it is used for feeding animals, or, in the case of fat, for making soap, it is not an absolute loss. That which we consume in excess of our needs is worse than wasted, beause of the harm it does to health.

In connection with the studies of dietaries cited in the previous pages, some observations have been made which bear upon this prevalent habit of throwing away valuable food. Thus, in the dietary of a carpenter, 7.6 per cent. of the total food purchased was left in the kitchen and table wastes. The total waste was somewhat worse than this proportion would imply, because it consisted mostly of the protein and fats, which are more costly than the carbohydrates. The waste contained about one-tenth of the total protein and fat, and only one-twenty-fifth of the total carbohydrates of the food ; or, to put it in another way, the food purchased contained nearly 10 per cent. more protein, 12 per cent. more fat, and 5 per cent. more carbohydrates than were eaten ; and worst of all, for the pecuniary economy or lack of economy, the wasted protein and fats were mostly from the meats, which supplied them in the costliest form. At the rate in which the nutrients were actually eaten in this dietary, the protein and fats in the waste would have each supplied one man for a week, and the carbohydrates for three days.

Among the dietaries of which details were given by Mr. C. D. Woods in the Annual Report of this Station for 1891, was that of a boarding house in Middletown. From the statistics of the amounts and composition of the table and kitchen wastes it appears that these contained one-ninth of the whole nutritive material of the food purchased. They included one-fifth of the protein and fats and one-twentieth of the carbohydrates. The protein and fats are costlier than the carbohydrates at best, and here again the rejected portions were mostly from the meats which supply them in the costliest forms. Except in so far as parts of the waste were fed to chickens or possibly used for soap, it was simply thrown away. The boarding house was a very good one, the mistress was counted an excellent housekeeper, and the boarders were mechanics and other thrifty and industrious people with only moderate incomes.

In the studies of dietaries of students' clubs in Middletown, referred to in the report of the Station for 1891, Mr. C. S. Videon had occasion to collect data regarding the meats used. Since not the whole of the meat was eaten, it was necessary to determine the weight and composition of the rejected portion. In buying meat in the retail markets in this region it is a common practice to have the bone and considerable of the fat cut out and left. In thus removing the "trimmings" the butcher is apt to cut out considerable else than the bone and the fat, as an observation by Mr. Videon illustrates. In a piece of roast beef weighing 16 pounds, the "trimmings," which consisted of the bone and the meat cut out with it, and which were left for the butcher to sell to the soapman or get rid of as he might otherwise choose, weighed 4½ pounds, so that 11½ pounds of meat went to the consumer, who, of course, paid for the whole. The butcher said that he sold this sort of beef largely to the ordinary people of the city—mechanics, small tradesmen and laborers; that many of his customers preferred not to take the "trimmings" and that they were not exceptionally large in this case, either in amount or in proportion of meat and bone, for that "cut" of beef, which was the "rib-roast." Inquiries of other meat-men brought similar information.

The 4½ pounds of "trimmings" consisted of, approximately, 2¼ pounds of bone and ½ pound of tendon ("gristle"), which would make a most palatable and nutritious soup, and 1¾ pounds of meat, of which 1 pound was lean and ¾ pound fat. Mr. Videon estimates that the nutritive materials of meat thus left unused, saying nothing of the bone and tendon, contained some 15 per cent. of the protein and 10 per cent. of the potential energy of the whole. The price of the beef was $2.24. Assuming the nutritive value of the ingredients of the "trimmings" to be 12½ per cent. of the whole, 28 cents worth of the nutritive material, besides the bone and tendon, was left at the butcher's.

In this connection I may perhaps be permitted to repeat some further statements which have been made in another place.* Dr. S. A. Lattimore, Professor of Chemistry in the University of Rochester, New York, tells me that while a member of the Board of Health of that city he directed the officer in charge of the collection of garbage to note the character of the waste material. It was ascertained that from the streets inhabited by the well-to-do classes, where the culinary affairs were largely left to the servants, the amount of waste thus collected was enormous, and that a considerable proportion of the food purchased was literally thrown away by careless servants. A surprisingly large amount of this waste consisted of good bread. Among the people in moderate circumstances this waste was less.

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*Century Magazine, January, 1888.

Still, people of moderate means do not save as they might. A gentleman from Pennsylvania, who has for years been in the way of employing hundreds of mechanics and other laborers, tells me that in passing by the houses where his employés live he is constantly pained to notice the evidences of waste of food which would not occur in his own household.

Concerning the amounts of food which we waste by excessive eating, much was said in the last Annual Report of the Station, and the subject is referred to beyond. It will, therefore, suffice to say here that the statistics at hand imply that we eat a large excess of the fatter kinds of meats, and of sugar and other sweetmeats.

Is not the American, of all civilized men, the most wasteful, and is not his worst wastefulness in his food—and drink?

The common saying that "the average American family wastes as much food as a French family would live upon," is a great exaggeration, but the statistics cited show that there is a great deal of truth in it. Even in some of the most economical families the amount of food wasted, if it could be collected for a month or a year would prove to be very large, and in many cases the amounts would be little less than enormous.

We endeavor to make our diet suit our palate by paying high prices in the market, rather than by skillful cooking and tasteful serving at home. We buy more than we need, and what makes the matter worse, it is frequently those who most need to save that are the most wasteful.

We waste at the store, at the market, and in the house, enough to make us wealthy if we would only save. The fathers and mothers do not understand the little arts of economy, and the sons and daughters do not learn them, and we are somewhat inclined to think it beneath our dignity as free-born and well-to-do American citizens to devote our attention to them. The remedy for the evil, so far as it applies to the chief item of our living expenses, our food, must be sought in two ways—in an understanding of the elementary facts regarding food and nutrition, and the acceptance of the doctrine that economy is not only respectable but honorable.

THE FOOD OF THE POOR.

That the rich man becomes richer by saving, and the poor man poorer by wasting his money, is one of the commonest facts of experience. It is the poor man's money that is the most uneconomically spent in the market, and the poor man's food that is worst cooked and served at home.

I can refer only to a single phase of this subject here, repeating for the purpose a few statements from an article on "Food Consumption" in the Report of the Massachusetts Labor Bureau for 1886:

"The agents of the Bureau in collecting the statistics of dietaries have made inquiries of tradesmen as to the kinds of food the poor of Boston purchase and the price they pay. . . .

"By poor people is meant those who earn just enough to keep themselves and families from want. When a groceryman or a marketman is asked, 'What is your experience in dealing with your poor customers in regard to the quality of food used by them?' the answer is, in almost every case, 'Oh, they usually want the best and pay for it, and the most fastidious are those who can least afford it.'

"In the matter of beef, for instance, the cuts most used for steak are the face of the round, costing from eighteen to twenty cents per pound; the tip of the sirloin, at from twenty to twenty-five cents; and rib-roast, at from eighteen to twenty cents. They do not use the flank-piece for steak, and would feel insulted if it were offered them. The flour they use is the best. For butter they pay from twenty-eight to thirty cents per pound at present prices. All their other groceries are such as are sold to first-class customers."

I took occasion some time since to make inquiries myself among the Boston marketmen. One very intelligent butcher, in Boylston Market, said:

"Across the street over there is an establishment which employs a good many seamstresses. One of them comes to my place to buy meat, and very frequently gets tenderloin steak. I asked her one time why she did not take round or sirloin, which is a great deal cheaper, and she replied, very indignantly: 'Do you suppose because I don't come here in my carriage I don't want just as good meat as rich folks have?' And when I tried to explain to her that the cheaper meat was just as nutritious, she would not believe me. Now Mr. —— and Mrs. ——, who are among the wealthy and sensible people of this city, buy the cheaper cuts of meat of me. Mr. —— very often comes and gets a soup bone, but I have got through trying to sell these economical meats to that woman and others of her class."

I am told that the people in the poorer parts of New York City buy the highest priced groceries, and that the meat-men say they can sell the coarser cuts of meat to the rich, but that people of moderate means refuse them. I hear the same thing in Washington and other cities. Indeed, to one who looks into the matter, it is surprising as it is pathetic to see how much people of limited incomes lose by such bad economy. Here it is sadly true that, "to him that hath shall be given, and from him that hath not shall be taken away even that which he hath."

FOOD AND HEALTH.

The studies of dietaries thus far made are not sufficient for entirely reliable inferences regarding the eating habits of the people at large. The total number of dietaries examined is only a little over fifty. They have been confined mostly to New England, only a small number of the examinations have been made with the needed accuracy, and it is worth noting that the ones in which the amounts and composition of the food have been most accurately determined are for the most part the ones in which the quantities were smallest, although some of the largest of the figures obtained were thought to represent very nearly the actual quantities.

Taking the results as they are, they very decidedly confirm the general impression of hygienists that our diet is one-sided and that we eat too much. As a result of a great deal of observation and experiment, physiologists have set up certain dietary standards which are intended to indicate in a general way the proportions of the different nutritive materials of food that are appropriate to people in different conditions of life. The dietaries here examined differ widely from these standards.

If we are to take the statistics which are summarized on page 173 as a fair indication of our eating-habits, our diet is one-sided; the food which we actually eat, leaving out of account that which we throw away, has relatively too little protein and too much fat, starch and sugar. This is due partly to our large consumption of sugar and partly to our use of such large quantities of fat meats. In the statistics referred to, the quantities of fat in the European dietaries range from one to five ounces per day, while in the American the range is from four to sixteen ounces. In the daily food of well-to-do professional men in Germany, who were amply nourished, the quantity of fat is from three to four and one-half ounces per day; while in the dietaries of Americans in similar conditions of life it ranges from five to seven and one-half ounces in the food purchased. The quantities of carbohydrates in the European dietaries range from nine to twenty-four ounces, while in the corresponding American dietaries the carbohydrates were from twenty-four to sixty ounces.

Chemists estimate the proportion of fuel ingredients to protein in what is called the "nutritive ratio." In this estimate one part by weight of fats is counted as equivalent to two and one-quarter of carbohydrates. Adding the two together gives the amount of the fuel ingredients. In the American dietaries the proportion of fuel ingredients to one part of protein ranges from six and six-tenths to eight and two-tenths, and even higher. In the European dietaries of well-nourished people and in the dietary standards which express the average needs according to the teachings of the best physiological observations, it is from four and one-tenth to six or thereabouts. The rejection of so much of the fat of meat at the market, and on our plates at the table is not mere willfulness. It is in obedience to nature's protest against a one-sided and excessive diet.

The dietary standards most commonly quoted are those of Prof. Voit, of Munich, Germany. The figures on page 173 show amounts of food consumed far in excess of these. They surpass even the liberal standards proposed tentatively by myself.

How much harm is done to health by our one-sided and excessive diet, no one can say. Physicians tell us that it is very great. Of the vice of over-eating, as practised by the well-to-do classes, in England especially, Sir Henry Thompson, a noted English physician and authority on this subject, says:

> "I have come to the conclusion that more than half the disease which embitters the middle and latter part of life is due to avoidable errors in diet, . . . and that more mischief in the form of actual disease, of impaired vigor, and of shortened life accrues to civilized man . . . in England and throughout central Europe from erroneous habits of eating than from the habitual use of alcoholic drink, considerable as I know that evil to be."

FOOD, WORK AND WAGES.

But there is another side to this story. It is found in the comparison of the food of wage-workers here and in Europe. The American workingmen, whose dietaries have been studied here, were better nourished by half than their trans-Atlantic brethren in like occupations. It looks as though ordinary people have with us what only the exceptionally well fed have on the continent of Europe, the food they need to make the most of themselves and their work. Indeed, is it not safe to say that so far as the facts at hand go, they imply very distinctly that to the American workingman is vouchsafed the priceless gift which is denied to most people of the world, namely, the physical conditions, including especially the liberal nourishment, which are essential to large production, high wages and the highest physical existence, and that as a corollary he has a like peculiar opportunity for intellectual and moral development and progress?

NEED OF RESEARCH.

In all this discussion, and the questions are fundamental for our home life, our national economy, and for our social and moral welfare, there is one difficulty. The subject is new, and definite information is wanting. The great need is for abstract inquiry. The underlying problems are the conservation of matter and the conservation of energy in the living organism. We shall not be able to tell how to get the most nutriment for our money and how to fit our food to our actual needs until these problems are more nearly solved. It is the old story, so true and yet so hard to make people believe—that the knowledge which, on the surface seems least practical, is really the most indispensable and the most useful. Part of the inquiry that is wanted can and doubtless will be carried on at public cost, but the kind which reveals the fundamental laws of biological chemistry requires the atmosphere and the appliances of the university, and can be accomplished only by the endowment of research.

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PUBLICATIONS OF THE STATION.

The publications of the Station will be mailed to all citizens of Connecticut, and to Granges, Farmers' Clubs, and other agricultural organizations who ask for them, and so far as circumstances permit, to those who apply from other States. Requests for publications should be addressed to

STORRS SCHOOL AGRICULTURAL
EXPERIMENT STATION,
TOLLAND COUNTY. STORRS, CONN.

STORRS SCHOOL
AGRICULTURAL EXPERIMENT STATION,

MANSFIELD, CONN.

BULLETIN No. 1. JUNE, 1888.

The purpose of this Bulletin is to explain to the public whom the Station is especially intended to serve, the organization of the Station, its spirit, and the character of the work thus far begun. It is the wish of those in charge of the enterprise to make its connection with the farmers of the State as intimate as possible, and to this end copies are mailed to all farmers in Connecticut whose addresses the Station has been able to obtain, to a number of other persons within and outside of the State, and to the press.

By the act of Congress provision is made for the appropriation of $15,000 per annum to each State and Territory, for the maintenance of Agricultural Experiment Stations. Of the fund for Connecticut, one-half is, by act of its last Legislature, entrusted to the Board of Control of the State Experiment Station, and one-half to the Board of Trustees of the Storrs Agricultural School, who are: —

His Excellency, PHINEAS C. LOUNSBURY.
E. H. HYDE,
J. M. HUBBARD,
WM. E. SIMONDS,
HENRY C. MILES,
T. S. GOLD,
J. P. BARSTOW,
* * * *
S. W. JOHNSON,

Two members of the Board, Messrs. T. S. Gold and J. M. Hubbard, with Prof. B. F. Koons, Principal of the School, constitute the Executive Committee of the Station. The appropriation was actually secured to the Storrs School in March last. As soon as practicable thereafter a Director and Vice-Director were appointed, who entered upon their duties April 1st, and arrangements were made to commence work at once. The following are the officers of the Station:

W. O. Atwater, Director.
C. S. Phelps, Vice-Director.
E. W. Rockwood, Chemist.
E. A. Bailey, Assistant.

At this early date it is not possible to outline exactly the future work of the Station. The chief immediate attention will be given to experiments upon the growth, nutrition, and fertilizing of plants, and the adaptability and value of different plants for culture in Connecticut. The work already begun includes:

I. Coöperative field experiments on the effects of fertilizers and the production of crops. These have been undertaken by the Station in Mansfield, and by a considerable number of farmers under the direction of the Station, in all the counties of the State.

II. Vegetation experiments in pots and boxes, for studying the question of the sources of the nitrogen of plants.

III. Arrangements for a Botanic Garden, to test the adaptability and values of grasses and other plants for culture in Connecticut. Fruits will also be tested, in accordance with the plan already established by the State Board of Agriculture, the Storrs School Farm being the Station for Tolland County.

Provision is being made for studies of the Root-development of plants, and of the Values of Foods and Feeding Stuffs, by chemical analysis and experiments with the calorimeter. As future circumstances allow, work in other lines will naturally be undertaken.

The farm and farm-appliances and the labor of the students of the Storrs School are utilized for the work of the Station. The botanic garden and other work at Mansfield and the field experiments throughout the State are under the immediate charge of the Vice-director. The more purely chemical investigations are carried out by the Director at Middletown, in the chemical laboratory of Wesleyan University, of which he has charge. This arrangement is decidedly advantageous to the Station as regards expense and otherwise, and telephone connections will make it entirely feasible.

FIELD EXPERIMENTS.

The field experiments with fertilizers are made by dividing experimental fields into plots, applying different fertilizing materials, and noting the amount and quality of the product. Those of the present season are of three kinds. The special object of the first, called "Experiments for Soil Tests," is to help farmers study the wants of their soils. In the experiments of the second class, different quantities of the fertilizing materials are used, the object being to get light upon the question as to what amounts are most profitable. The experiments of the third class are somewhat more complicated, and are planned for study of the effects of nitrogenous fertilizers upon different crops, and the ability of the plants to gather nitrogen from natural sources. The experiments are explained and directions for their conduct are given in a pamphlet prepared for this purpose, copies of which may be had on application to the Station at Mansfield. From this the following is quoted:

> The fertilizing materials and the method of conducting the experiments are the same for all the experiments of each class. The materials (with the exception of farm manures) are furnished by the Station. They supply nitrogen, phosphoric acid, and potash in standard commercial forms, as nitrate of soda, superphosphate, potash salts, etc. They are put up in bags; each bag bears a label describing the fertilizer; the bags for one experiment make a "set." It is expected that the principal part of the labor will be provided by the gentlemen on whose farms the trials are made. Observations will be made of temperature, rainfall, and other climatic conditions — with instruments for the purpose, in so far as practicable. The experimenters receive a pecuniary compensation which, with the information obtained, entitles the Station to the control of the work and its results. The Vice-Director or other representative of the Station will assist in selecting the land, laying out the experiments, and in harvesting and weighing the product. Part of the latter will be reserved by the Station for analysis and other tests of composition and value. As opportunity permits, an effort will be made toward the special study of some of the soils also.
>
> It is proposed to repeat a number of these experiments through a series of years, using the same fertilizers on the same plots year after year; in some cases with the same crops continuously, and in others with a rotation of crops. For the present year the larger number of the experiments will be with corn, the economical culture of which is a matter of growing importance in Connecticut, though some will be made with potatoes and perhaps other crops. It is hoped that in future years the enterprise may be extended to include trials with a variety of crops on the different soils of the State.

Experiments for Soil Tests. — These are carried out by the farmers on their own land, as a means of learning what fertilizing materials their soils lack, and how they may be most advantageously supplied. A plan of the experimental field is given on page 10. The following is part of the explanation in the pamphlet referred to:

> For the farmer to test his own land, and as a means for the study of the most profitable ways of fertilizing a soil of a given kind, the method of applying different fertilizing materials to different plots of fields on which crops are grown, is found, by long experience, to be, on the whole, decidedly advantageous.
>
> Experience in the field, explained by experiments in the laboratory, has clearly demonstrated that:
>
> 1. Soils vary greatly in their capabilities of supplying food to crops. Different ingredients are deficient in different soils.
> 2. Plants differ widely with respect to their capacities for gathering their food from soil and air. Hence the proper fertilizer in a given case depends upon the crop as well as upon the soil.
> 3. The chief use of fertilizers is to supply the plant-food which crops need and soils fail to furnish.
> 4. The only ingredients of plant-food which we need to consider in fertilizers are potash, lime, magnesia, phosphoric acid, sulphuric acid, and nitrogen. Of this list the magnesia is commonly, though not always, supplied in sufficient quantities in even "worn-out" soils. Sometimes its presence in fertilizers may be of considerable importance to crops. Sulphuric acid and lime are more often deficient, and hence one reason of the good effect so often observed from the application of lime and plaster. The remaining substances, the *phosphoric acid, potash,* and *nitrogen* are the most important ingredients of our common commercial fertilizers, because of both their scarcity in the soil and their high cost. It is in supplying these that phosphates, bone manures, potash salts, guano, nitrate of soda, and most other commercial fertilizers are chiefly useful.
> 5. It is not good economy to pay high prices for materials which the soil may itself furnish, but it is good economy to supply the lacking ones in the cheapest way.
> 6. The only way to learn what materials are proper in a given case is by observation and experiment. The rational method for determining what ingredients of plant-food a soil fails to furnish in abundance, and how these lacking materials can be most economically supplied, is to put the question to the soil with different fertilizing materials and get the reply in the crops produced.
> 7. The results of any given experiment are, in the main, applicable only to the particular case where it is made.
> 8. A single season's experimenting does not tell the whole story. To get complete results the trials must be carried through a series of years and crops.
>
> The kinds and quantities of materials and of valuable ingredients per plot and per acre are shown below. The experimental fertilizers are put

up in bags in quantities intended for one tenth acre. The eight bags thus suffice for eight plots of a tenth of an acre each, which, with two unmanured plots, make an acre. With unmanured strips between the plots to prevent the plants of one plot from feeding on the fertilizers of the adjoining plots, the experiment will cover somewhat over an acre.

EXPERIMENTAL FERTILIZERS FOR SOIL TESTS. ACRE SET.

Number of Bags.	Fertilizing Materials.			Valuable Ingredients.		
	Kinds.	Amounts.		Kinds.	Amounts.	
		Per Plot. lbs.	Per Acre. lbs.		Per Plot. lbs.	Per Acre. lbs.
A.	Nitrate of Soda,	15	150	Nitrogen,	2.4	24
B.	Dissolved Bone-Black,	35	350	Phos. Acid,	5.6	56
C.	Muriate of Potash,	15	150	Potash,	7.5	75
D.	Nitrate of Soda,	15	150	Nitrogen,	2.4	24
	Dissolved Bone-Black,	35	350	Phos. Acid,	5.6	56
E.	Nitrate of Soda,	15	150	Nitrogen,	2.4	24
	Muriate of Potash,	15	150	Potash,	7.5	75
F.	Dissolved Bone-Black,	35	350	Phos. Acid,	5.6	56
	Muriate of Potash,	15	150	Potash,	7.5	75
G.	Nitrate of Soda,	15	150	Nitrogen,	2.4	24
	Dissolved Bone-Black,	35	350	Phos. Acid,	5.6	56
	Muriate of Potash,	15	150	Potash,	7.5	75
H.	Plaster,	40	400			

Besides these it will be well to test the action of farm manures, lime, and other fertilizing materials.

In brief, the plan of these experiments for soil tests consists of applying on parallel plots of land, fertilizers containing nitrogen, phosphoric acid and potash, each by itself, two by two, and all three together. Experiments of this kind are being conducted by

F. M. Hawley,	New Canaan,	Fairfield County.
A. C. Blake,	New Britain,	Hartford County.
T. A. Kirkham,	Newington,	Hartford County.
S. T. Stockwell,	West Simsbury,	Hartford County.
R. S. Hinman,	Birmingham,	New Haven County.
J. P. Inglis,	Middlefield,	Middlesex County.
H. F. Cox,	Brooklyn,	Windham County.
Frank Day,	Danielsonville,	Windham County.
N. G. Williams,	Brooklyn,	Windham County.
L. H. Healy,	No. Woodstock,	Windham County.

EXPERIMENTS WITH DIFFERENT QUANTITIES OF FERTILIZERS.

Farmers wish to know not only what kind of fertilizer, but how much they can most profitably use. Many apply larger quantities than used to be thought advisable, because they find that liberal manuring is often the most profitable manuring. But the best quantity depends upon a great variety of conditions, and accurate tests are needed to show the range of profit. The Station has instituted a few experiments in this direction with chemical fertilizers on potatoes. As will be seen on the diagram on page 10, the plan consists in applying three different quantities of the same fertilizer on three parallel plots, and noting the effect upon the crop.

Potatoes are in many places a very important crop, and commercial fertilizers are largely used in growing them. It is found that they generally respond to all three of the more costly ingredients of commercial fertilizers, nitrogen, phosphoric acid, and potash; that, in other words, a "complete fertilizer" is generally in place for potatoes. Nitrate of soda is used for nitrogen, dissolved bone black for phosphoric acid, bone dust and Peruvian guano for phosphoric acid and nitrogen, and muriate and sulphate of potash for potash ; on the hypothesis that the ingredients combined in different forms may be more efficient than when each is used in only one form. A mixture of these materials containing six per cent. of nitrogen, eight per cent. of phosphoric acid and eleven per cent. of potash is put in bags of thirty or sixty pounds each, to be used on one-twentieth-acre or one-tenth acre plots. This would be equivalent to 600 pounds per acre, furnishing 3.6 pounds of nitrogen, 4.8 pounds of phosphoric acid, and 6.6 pounds of potash. The bags are numbered I. One will be used on plot I, two on plot II, and three on plot III. This makes 600, 1,200, and 1,800 pounds of the fertilizer per acre. Even the largest amount is less than is sometimes profitable for potatoes.

On account of the danger of tests of this sort being vitiated by irregularities of soil the experiment is duplicated, two groups of three plots each being included. On each side of each of these groups of plots on which the three different quantities of fertilizer are applied, is a plot with a mixture of superphosphate and potash salt (called "Mixed Minerals"). These serve to test the evenness of the soil and the amount of produce without nitrogen. One plot at each end of the experimental field is left unmanured to show what the soil will do.

Experiments of this sort are being conducted by the following gentlemen, Mr. Kirkham's being in connection with a "soil test" experiment.

T. A. Kirkham,	Newington,	Hartford Co.
H. S. Merwin,	Durham,	Middlesex Co.
H. H. Hubbard,	Middletown,	Middlesex Co.

EXPERIMENTS FOR STUDYING THE EFFECTS OF NITROGEN IN FERTILIZERS. — SPECIAL NITROGEN EXPERIMENTS.

Farmers in Connecticut, as in all the older States of this country and in Europe, are spending untold amounts of money every year for nitrate of soda, sulphate of ammonia, fish scrap, dried blood, guano, ammoniated superphosphate, and the like. Ostensibly, they are buying the fertilizers at from $10 to $100 per ton. Actually they are buying nitrogen at from ten to thirty cents per pound. But need the farmer spend so much for nitrogen? Or might he use more with profit? These are questions that no one to-day can answer. Indeed, no chemist or botanist can, as yet, so much as tell him how the different plants he cultivates stand related to nitrogen, for just what ones he must buy it, and what ones he may use in rotation with other crops to gather it from nature's stores and furnish it to him without money and without price, save the cost of tillage.

The question of the nitrogen supply is only one of a great many whose solution is most urgently demanded. We must know how to feed our plants or go without food ourselves. We need more light. Some must come from the laboratory and the greenhouse; some must be sought in the field.

Field experiments rationally planned, carefully carried out, faithfully reported, and interpreted with the aid of the most advanced science, will carry us far toward finding out many of the things which we so much want to know. If, along with these, we can have proper studies, chemical and physical, of the soils experimented upon, analyses of the plants produced, and, in addition, pot experiments whose conditions can be definitely known and controlled, we may hope to gradually obtain the information we need.

THE FEEDING CAPACITIES OF PLANTS.

A vast deal of experience in the laboratory and in the field bears concurrent testimony to the fact, though we are still deplorably in the dark as to how or why it is so, that different kinds of plants have different capacities for making use of the stores of food that soil and air contain. Of the ingredients of plant food in our soils, the most important because the most costly, is nitrogen. Leguminous crops, like clover, do somehow or other gather a good supply of nitrogen where cereals, such as wheat, barley, rye, and oats, would half starve for lack of it, and this in the face of the fact that leguminous plants contain a great deal of nitrogen, and cereals relatively little. Hence a heavy nitrogenous manuring may pay well for wheat and be in large part lost on clover.

The tendency of late research is to indicate that some, at least, of the plants that make little response to nitrogenous manuring, obtain nitrogen from the air. Whatever the facts may be, they are of the greatest importance. Whatever can be done to bring new light upon the problem is worth attempting. One interesting fact brought out by late experimenting is that the corn plant seems possessed of a goodly share of this faculty of obtaining nitrogen from natural sources, though it is by no means safe to say, at present, that it draws much of its nitrogen directly from the atmosphere. But the power it appears to have of getting its own nitrogen, whether from soil alone, or from both soil and air, means more for the future of corn culture in New England than farmers have yet come to realize.

Several of the Annual Reports of the Connecticut Board of Agriculture have contained accounts of field experiments devised for the study of this especial question and carried out by a number of farmers, agricultural colleges, and experiment stations, in Connecticut and elsewhere. The idea is to use the "mineral" fertilizers, superphosphate, and potash salt (which are here called "mixed minerals," and supply all of the ingredients of a "complete fertilizer" except nitrogen) as a basis of comparison, and to compare the produce from this mixture with that obtained when nitrogenous materials are added to it; the increased yield in the latter cases being attributed to the nitrogen.

The following schedule provides for twenty plots, of which two are unmanured, and eighteen supplied with the experimental fertilizers. Of the latter, three, Nos. 6a, 6b, and 6c are duplicates of the "Mixed Minerals," No. 6. This gives four plots of "mixed minerals," one on each side of each of the three groups, III, IV, and V, in which latter the effects of nitrogen are to be tested. This duplicating the "mixed minerals" serves the three-fold purpose of testing the uniformity of the soil, replacing unmanured plots, and showing more accurately the actual effects of the nitrogen.

The plan of the experimental field is shown by the diagram on page 11. The fertilizers are as in the subjoined tabular statement.

FERTILIZING MATERIALS FOR SPECIAL NITROGEN EXPERIMENTS.

	Fertilizers.				Nitrogen per acre.
	Kinds.	Amounts per plot.		Amounts per acre.	
		Two-acre Set, for 1-10 acre plots.	One-acre Set, for 1-20 acre plots.		
	PRELIMINARY GROUP.	Pounds.	Pounds.	Pounds.	Pounds.
1.	Nitrate of soda,	15.	7.5	150.	24.
2.	Superphosphate,	35.	17.5	350.	
3.	Muriate of potash,	15.	7.5	150.	
4.	Nitrate of soda,	15.	7.5	150.	24.
	Superphosphate,	35.	17.5	350.	
5.	Nitrate of soda,	15.	7.5	150.	24.
	Muriate of potash,	15.	7.5	150.	
6.	Superphosphate, } Mixed minerals,	35.	17.5	350.	
	Muriate of potash,	15.	7.5	150.	
	NITRATE OF SODA GROUP.				
7.	Mixed minerals, as No. 6,	50.	25.0	500.	
	Nitrate of soda, one-third ration,	15.	7.5	150.	24.
8.	Mixed minerals, as No. 6,	50.	25.0	500.	
	Nitrate of soda, two-thirds ration,	30.	15.0	300.	48.
9.	Mixed minerals, as No. 6,	50.	25.0	500.	
	Nitrate of soda, full ration,	45.	22.5	450.	72.
6a.	Mixed minerals, as No. 6,	50.	25.0	500.	
	SULPHATE OF AMMONIA GROUP.				
10.	Mixed minerals, as No. 6,	50.	25.0	500.	
	Sulphate of ammonia, one-third ration,	11.2	5.6	112.	24.
11.	Mixed minerals, as No. 6,	50.	25.0	500.	
	Sulphate of ammonia, two-thirds ration,	22.4	11.2	224.	48.
12.	Mixed minerals, as No. 6,	50.	25.0	500.	
	Sulphate of ammonia, full ration,	33.6	16.8	336.	72.
6b.	Mixed minerals, as No. 6,	50.	25.0	500.	
	DRIED BLOOD GROUP.				
13.	Mixed minerals, as No. 6,	50.	25.0	500.	
	Dried blood, one-third ration,	22.	11.0	220.	24.
14.	Mixed minerals, as No. 6,	50.	25.0	500.	
	Dried blood, two-thirds ration,	44.	22.0	440.	48.
15.	Mixed minerals, as No. 6,	50.	25.0	500.	
	Dried blood, full ration,	66.	33.0	660.	72.
6c.	Mixed minerals, as No. 6,	50.	25.0	500.	

In brief these experiments test the effects of nitrogen in different forms and amounts. They are being made, this season, on corn, by

THE STATION,	Mansfield,	Tolland County.
M. H. DEAN,	Falls Village,	Litchfield County.
J. H. ATKINS,	Middletown,	Middlesex County.
E. H. LATHROP,	Vernon Center,	Tolland County.
L. J. WELLS,	So. Woodstock,	Windham County.
W. I. BARTHOLOMEW,	Putnam,	Tolland County.
JOHN B. PERRY,	Clark's Falls,	New London County.

Mr. Atkins and Mr. Perry are graduates of the Storrs Agricultural School. Mr. Atkins' Special Nitrogen Experiment and Mr. Hubbard's experiment upon the effects of different quantities of the "complete fertilizer" are on contiguous fields and form really one experiment, a combination which has decided advantages.

EXPERIMENT FOR SOIL TEST.

Plan of Experimental Field.

Whole field, one acre, or more with farm manures or other fertilizers and with unmanured strips between each two plots.

0	No Manure.
A	Nitrate of Soda.
B	Superphosphate.
C	Muriate of Potash.
D	Nitrate of Soda and Superphosphate.
E	Nitrate of Soda and Muriate of Potash.
F	Superphosphate and Muriate of Potash. "Mixed Minerals."
G	Nitrate of Soda, Superphosphate, and Muriate of Potash.
H	Sulphate of Lime (Plaster).
	Farm Manure.
00	No Manure.

EXPERIMENT TO TEST EFFECTS OF DIFFERENT QUANTITIES OF FERTILIZERS ON POTATOES.

Plan of Experimental Field.

0	No Manure.
	Superphosphate and Potash Salt (Mixed Minerals).
I	Complete fertilizer, 1 bag — 600 lbs. per acre.
II	Complete fertilizer, 2 bags — 1,200 lbs. per acre.
III	Complete fertilizer, 3 bags — 1,800 lbs. per acre.
	Superphosphate and Potash Salt.
I	Complete fertilizer, 1 bag — 600 lbs. per acre.
II	Complete fertilizer, 2 bags — 1,200 lbs. per acre.
III	Complete fertilizer, 3 bags — 1,800 lbs. per acre.
	Superphosphate and Potash Salt.
0	No Manure.

SPECIAL NITROGEN EXPERIMENT.

Plan of Experimental Field.

With "Acre Set." Each plot $\frac{1}{20}$ acre.
Whole field one acre.
With "Two Acre Set." Each plot $\frac{1}{10}$ acre.
Whole field two acres.
Or more with unmanured strips between each two plots.

0	No Manure.
1	Nitrate of Soda.
2	Superphosphate.
3	Muriate of Potash.
4	Nitrate of Soda and Superphosphate.
5	Nitrate of Soda and Muriate of Potash.
6	Superphosphate and Muriate of Potash. "Mixed Minerals."
7	Mixed Minerals plus Nitrate of Soda. ⅓ Ration.
8	" " Nitrate of Soda. ⅔ "
9	" " Nitrate of Soda. Full Ration.
6*a*	Mixed Minerals. Duplicate of No. 6.
10	Mixed Minerals plus Sulphate of Ammonia. ⅓ Ration.
11	" " Sulphate of Ammonia. ⅔ "
12	" " Sulphate of Ammonia. Full Ration.
6*b*	Mixed Minerals. Duplicate of No. 6.
13	Mixed Minerals plus Dried Blood. ⅓ Ration.
14	" " Dried Blood. ⅔ "
15	" " Dried Blood. Full Ration.
6*c*	Mixed Minerals. Duplicate of No. 6.
00	No Manure.

The pamphlet prepared for the experimenters lays special stress on the sources of error in field experiments and the means for avoiding them, and gives full directions for conducting them and making out reports. Their spirit may be inferred from the following passages:

The most satisfactory way to arrange field experiments is to grow crops without manure until the land is thoroughly worn down, and at the same time, by measuring the produce from plots, test the uniformity of the soil. This is being done by the Station on land of the Storrs School Farm at Mansfield.

"What is worth doing is worth doing well." In furtherance of the purpose of the experiment and its best execution, please note:

The "Condensed Directions." — This slip is intended to be taken into the field for use in laying out the experiment.

The Blank for Report. — This will be furnished by the Station. Please look it over while the crop is growing, consider what it asks for, and make up your mind how to collect the facts. If ways of improving the plan occur to you, please suggest them, and if agreed to on consultation, adopt them, and at any rate accept thanks.

Everything in order before Starting. — Have your plans complete and clearly in mind, and everything ready before you start. Proper plans at the outset; uniform soil for all the experiments; "worn-out" soils for the soil tests; plots of proper size, shape, and accurately laid out; right application of the fertilizers; good seed; careful measurement of crops; full notes of details; and careful observation of the effects of the fertilizers on succeeding crops, are essential to the best results.

Uniform soil. — The soil should be as nearly uniform in quality as possible. There will be more or less variation in different parts of the same field at best. The less there is of this, the more reliable will be the experiment. Level land should be chosen if practicable, but if it is sloping, let the plots run up and down the ascent so that wash by rains will not transfer the materials from one plot to another. Of course the portion chosen for experiment should be a fair sample of the whole field.

"Worn-out" soils for soil tests. — Select "worn-out" soil. You want to learn what the soil itself can do by its own natural strength, not what it will do with the aid of a store of plant-food, which has been either accumulated by natural processes or left over from previous manuring, and will obscure the action of the fertilizers.

Lay out plots accurately. — Lay out the whole experimental area and the individual plots as accurately as you can. Measure with chain or tape, if you have it, otherwise with pole marked in feet and inches. Drive good strong stakes firmly into the ground at the boundaries so that you may be able to tell in this and coming seasons where the divisions are. There should be four stakes for each plot, one at each corner. These will show the boundaries of the plots and of the unmanured space between them. The stakes for each plot can be marked with the number of the plot (A, B, C, etc., for the Soil Tests, and 1, 2, 3, etc., for the Special Nitrogen Experiments). Cut the marks in the stakes with a knife. The tag on the bag can be tied to one of the stakes of the plot to which it belongs.

In general, an unmanured strip at least two or three feet, and better, four feet, wide should be left between each two plots, so as to prevent the plants of one from being affected by the manure of another. In experiments with corn or potatoes these strips may be planted with potatoes. With other crops, as oats, it may be more convenient to have them unmanured.

Fertilizers well diffused through soil. — The fertilizers may be applied broadcast, or if more convenient, they may be put in the hill or drill, *provided, they are well diffused through the soil.* To accomplish this, they had better be diluted with several times their bulk of earth before using. The important points are, that they be:

1st. Applied evenly over the plots where they belong and not allowed to get outside.

2d. Well distributed through the soil.

Experiments with concentrated fertilizers are often spoiled, just as crops are injured or lost through wrong application. Farmers are apt to think the manure must be put close to the seed or the plant will not get the benefit of it. This is wrong. It is not the just germinated plantlet that needs the manure, but the plant, from the time it is well started until its growth is done. We want, not only to give the crop a good start, but to help it out on the homestretch as well. The roots and their branching rootlets run out in all directions in search of food, and the fertilizers ought to be where as many of the rootlets as possible can get at them. If we distribute the fertilizers as well as we can, the water in the soil, aided by the chemical and physical forces that nature keeps in operation, will do the rest. In illustration of this, remember how well barn-manure acts when applied as a top-dressing long before the seed is put in.

But if we concentrate the fertilizers in one place fewer roots will get them, and these may be injured by coming in contact with them or with their concentrated solutions in the soil. The roots will find their way to the manure and develop more where it lies, it is true, still we should not oblige them to huddle together in one place, but should rather encourage them to spread around, where, with the increased capacity the fertilizer gives them, they can get the more from the soil. Roots join with other natural agents in rendering inert stores of plant-food available.

Above all, do not let the fertilizers come too close to the seed. A coarse, dilute material like yard manure may do the plants no harm, but such concentrated fertilizers as potash salts, nitrate of soda, dried blood, or high grade superphosphates may kill them.

Unmanured Plots for Comparison. — It is of the greatest importance that several unmanured plots be left for comparison. For eight manured plots, two unmanured will suffice; but where there are more than that, three, one at each side, and one in the middle, or, if the number is large, one in the middle and one-half between this and each side would be advisable. You will have very little idea how uneven an apparently uniform soil may be until you make the trial.

Other Fertilizers to be Tried. — It will be well, in the soil tests especially, to try other materials along with the experimental one. Farm manures, ashes, and especially lime, are to be recommended.

See that all is done Rightly. — Attend to the work yourself. Don't trust it to the hired man unless you are sure he will do it better than you can.

Make Accurate Observations. — Watch the experiments closely. Note your observations. Make them both as accurate and complete as you can. Put down your notes when you make your observations. Do not trust them to future recollection.

Reports. — Make your reports as full and accurate as possible. Keep one copy for your own future use, and send the other in so that your results may be compared and published with others in good season. The benefit will not be yours alone, but you will share with others the good that will come from the combined work of all.

Plans for Continuing the Experiments in Coming Years. — To give the experiments their proper value they should be continued through a series with the same fertilizers on the same plots, and with either a rotation of crops or with the same crop year after year, it is hoped that a considerable number of the experiments may be thus repeated. For this the stakes bounding the plots must be kept in place.

The Station has thus instituted some twenty of these coöperative field experiments with fertilizers in the State, from one to five in each county, the present season. The most of them are with corn, though several are with potatoes. Later in the season it is hoped that some may be made with turnips.

Experiments have also been undertaken on the adaptability and value of certain plants for summer-feeding and green-manuring.

Some of the most accurate, thorough, and valuable field experiments ever made in this country have been carried out by Connecticut farmers. The list of experimenters working with the Station this season, includes some of these gentlemen. It is especially gratifying that a number of young men have joined in the work.

It is believed that the value of such work as this is not confined to the information which it brings, useful as that may be both to the experimenters and to farmers in general, but that it has a higher importance in promoting sympathy between science and the practice of agriculture, and in the educating influence it exerts.

INVESTIGATIONS ON THE SOURCES OF THE NITROGEN OF PLANTS.
SAND-CULTURE AND WATER-CULTURE.

Late research in this country and in Europe, implies that some plants have the power of getting nitrogen from the air. How they obtain it, how much is gathered by the foliage and how much comes through the soil and the roots of the plants, are things to be found out. If there are plants that can draw this scarcest and costliest of all the elements of plant-food from the air it is important to know what plants they are and the circumstances under which they get it. If the nitrogen must first be introduced into the soil, by natural processes or by manuring, we need to know how this can be done most economically.

How much nitrogen plants can obtain from the atmosphere, is a problem best studied by experiments on a small scale in the green-house and laboratory. For the investigation of this latter question, which has a high scientific as well as practical importance, the Station has begun a series of experiments in pots by the method of sand and water culture. Late research implies that the minute organisms called microbes or bacteria may have something to do with the acquisition of atmospheric nitrogen. This especial problem is being studied in connection with the experiments on nitrogen supply under the immediate supervision of the Director.

Botanic Garden.

In the Grass and Forage Garden at Mansfield about seventy-five different species and varieties of grasses, legumes, and other fodder plants have been sown and quite a number of sods have been set out. It is hoped that the number and varieties of plants may be greatly increased throughout the season and in following years. The Station desires, with other things, to test the different grasses produced in Connecticut, including those found in old meadows and pastures in all parts of the State. It invites individual farmers, agricultural societies and granges to send samples of sod to be set out in the garden at Mansfield. They should be six inches square, carefully packed, and accompanied by full descriptions of location and soil. If they are forwarded to the Storrs School Agricultural Station, Eagleville, the express charges will be paid by the Station. Parties proposing to send are, however, requested to first correspond with the Station.

Specimens of seeds of tested purity have already been furnished by the Connecticut (New Haven) and Massachusetts Stations.

The Station and The Farmer.

The Managers of the Station recognize that its purpose is both to investigate and to teach; that its duty is to select for study such questions as are of the most immediate and practical importance to the agriculture of the State; and that its work will be successful in proportion to the intimacy of its connection with the farmers whom it represents. But they feel bound to accept the lesson taught by years of experience, in this country and elsewhere, that the most valuable results will be obtained by selecting a small number of questions for investigation, by making them narrow and specific, and by studying, them with the greatest possible thoroughness. And they desire to avoid, so far as may be, the error into which so many Stations, in their early experience, have fallen, in failing to recognize that often the questions which seem most theoretical are really most practical; that the highest, and on the long run, the most useful work for agriculture is the discovery of the laws that underlie its practice and that not infrequently the interests of the farmer require that theoretical questions be considered first, for the same reason that the foundation of the house is the first part to be built. In using part of its resources for abstract research, the managers of the Station feel assured that it is doing its highest duty and will have the heartiest support of its constituency.

Further accounts are reserved for future Bulletins and reports in the belief that the Station should be known by its accomplished, rather than its promised, results.

The publications of the Station will be mailed to all citizens of Connecticut, who ask for them, and to those of other States so far as circumstances permit. Requests for publications and business communications should be addressed to

Storrs School Agricultural Experiment Station,
Mansfield, Conn.

To resume: the Station is endeavoring to accomplish the purpose for which it was established, by painstaking research in pure science, by practical experimenting, by placing itself in the closest relations with the farmers of the State, and by securing their coöperation in its work. Its managers believe that if the interest and support of the farmers are equal to the effort of the Station to serve them, its success will be assured.

W. O. ATWATER, *Director.*

STORRS SCHOOL
Agricultural Experiment Station,
MANSFIELD, CONN.

BULLETIN No. 2. OCTOBER, 1888.

By the Act of Congress, $15,000 per annum are appropriated to each State and Territory for the maintenance of Agricultural Experiment Stations. Of the fund for Connecticut, one half is, by act of its Legislature, entrusted to the Board of Control of the State Experiment Station at New Haven, and one half to the Board of Trustees of the Storrs Agricultural School at Mansfield.

The Station was organized in April, 1888. Its officers are:—

EXECUTIVE COMMITTEE.

T. S. Gold, West Cornwall,	*Of the Board of Trustees of the Storrs Agricultural School.*
J. M. Hubbard, Middletown,	
B. F. Koons, Mansfield,	*Principal of the School.*

TREASURER.

John P. Barstow,	*Norwich.*

WORKING FORCE.

W. O. Atwater,*	*Director.*
C. S. Phelps,	*Vice-Director.*
C. D. Woods,	*Chemist.*
H. B. Gibson,	*Assistant Chemist.*
E. A. Bailey,	*Assistant in Farm Experiments.*

The first Bulletin of this Station, June, 1888, contained the following statement:—

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* Is at present engaged in the work of the U. S. Department of Agriculture, in connection with the Experiment Stations, but still retains an oversight of the work of this Station.

"The purpose of this Bulletin is to explain to the public, whom the Station is especially intended to serve, the organization of the Station, its spirit, and the character of the work thus far begun. It is the wish of those in charge of the enterprise to make its connection with the farmers of the State as intimate as possible, and to this end copies are mailed to all farmers in Connecticut whose addresses the Station has been able to obtain, to a number of other persons within and outside of the State, and to the press."

The present Bulletin, and the future publications of the Station, will be mailed to all citizens of Connecticut, to Granges, Farmers' Clubs, and other agricultural organizations, who ask for them, and to those of other States so far as circumstances permit. Requests for publications and business communications should be addressed to

Storrs School Agricultural Experiment Station,
Mansfield, *Conn.*

The field experiments, and the investigations on the sources of the nitrogen of plants, and the laboratory work mentioned in the previous Bulletin, are in progress and will be reported later.

The present Bulletin contains brief accounts of (1) Experiments on Effects of Surface Tillage, (2) Meteorological Observations, and (3) the Grass and Forage Garden.

EXPERIMENTS ON THE EFFECTS OF TILLAGE ON SOIL MOISTURE.

Many farmers have observed that hoeing and cultivating the soil help crops to withstand drouth, but the fact that such tillage is often worth more than manure, and the reason why it is so useful, are things that need to be better understood. The reasons are found out by experiment. Much has thus been learned; more needs to be discovered.

The Act of Congress establishing the Experiment Stations makes it their duty both to "conduct original researches" and to "verify experiments." The Station has undertaken, on the farm of the School at Mansfield, a series of experiments on the evaporation of soil moisture, especially as affected by surface tillage. They were planned by C. S. Phelps, Vice-Director of the Station, and carried out under his immediate supervision. As the work progresses, the purpose is to publish detailed accounts in the reports of the Station. The experiments thus far made have revealed no new principles,—indeed, they are still crude and only tentative, and will need various modifications in the future; but they confirm the results of other experiments in explaining the value of surface tillage.

DESCRIPTION OF THE EXPERIMENTS.

The details of the experiment are as follows:—

Eight cans made of galvanized iron, each 30 inches deep and 10 inches in diameter, were used for holding the soil. Two inches above the bottom, on the outside, was soldered a half-inch lead pipe, to which was attached rubber tubing extending to the top of the can. Through this tubing weighed quantities of water were added when desired. In the soil as it naturally lies, the water has free passage downwards and upwards, but the bottoms of the cans cut off communication between the soil in them and that in the earth in which they stand. Since, therefore, no water could come into them from below to make up for that which was evaporated, this means was taken to supply water in times of drouth. Boxes of one and one-half inch chestnut plank, without bottoms, of the same height as the cans and large enough to hold them, were sunk into the earth in the forage garden, so that the tops were even with the surface of the ground. The cans of soil were kept in these boxes, and removed only for weighing. The surface of the soil within the cans was at the same level as that of the ground outside. On the top of each can a thin cylinder of galvanized iron, 2 inches high and 10 inches in diameter, was accurately fitted. These cylinders served as rain gauges, conducting the same amount of rainfall into each can. The rainfall for August being above the average, water was added artificially but twice, all the cans receiving the same amounts.

Two kinds of soil were used for the experiments; one was from rather low land, that of the grass and forage garden, and the other from grass-land on the top of the hill near the laboratory of the School. The cans were filled so that the soil stood, as nearly as possible, at the same depth in the cans as it previously did in the fields from which it was taken. That is, soil from a depth of 20 to 30 inches was placed in the bottom ten inches of the can; soil from a depth of 10 to 20 inches in the middle ten inches; and the upper part of the can was filled with the surface soil. The earth was put into the cans in successive layers of about one inch in depth, and each layer gently tamped. This was to make the soil in the cans as uniform in compactness as possible.

The eight cans were divided in two lots of four each. The soil in one lot was the heavy loam with clayey subsoil; that in the other, light loam with sandy subsoil. The surface of the soil in the two cans of each lot was stirred frequently,—one to a depth of two, and the other, four inches, while that in the other two cans was left undisturbed.

Lot I.—Soil from forage garden. Subsoil, lower twenty inches, a yellow clay loam of nearly uniform texture. Surface soil, top of can, a rich, heavy loam.

Lot II.—Upland soil. Ten inches at bottom of can nearly pure sand. Middle ten inches, porous, light loam. Remainder, top of can, from first five inches below the sod, a light loam, apparently containing small percentage of organic matter.

The experiment was commenced July 31st, but heavy rains interfered at times. In one case more water fell than the soil in the cans could readily absorb, so that the cans were flooded. The period between August 15th and August 31st, however, was for the most part dry and warm enough to show clearly the effects of evaporation, though it was by no means a time of drouth. The figures given in the following table are for this period of sixteen days:—

LOSS BY EVAPORATION FROM AUG. 15 TO AUG. 31.

CONDITION OF SURFACE.	IN POUNDS AND OUNCES.				IN INCHES.	
	Lot I. Heavy Soil.		Lot II. Light Soil.		Lot I. Heavy Soil.	Lot II. Light Soil.
	Lbs.	Oz.	Lbs.	Oz.	In.	In.
Not stirred, -	4	13.0	3	5.0	1.69	1.16
Not stirred, -	4	9.0	4	2.5	1.62	1.46
Stirred 2 inches,*	3	10.5	1	12.5	1.29	0.62
Stirred 4 inches,*	3	8.0	2	3.0	1.23	0.77

*Stirred every alternate day, unless prevented by rain.

The amounts of water the soil lost by evaporation are given in pounds and ounces, and in inches. The figures for pounds and ounces represent the weight of water lost by evaporation from each can. Allowance is made for the water which fell as rain and for that artificially added, but not for the very small amounts received from dew or absorbed from the atmosphere as hygroscopic moisture. The surface of each can was 78.5 square inches. One pound for this surface would correspond to one pound and thirteen ounces for one square foot, or forty tons per acre. In expressing the loss in inches, the term has been used with the same meaning as is customary in stating the amount of rainfall. One inch of rainfall means enough water falling in rain to cover the surface of the given locality to the depth of one inch. When it is stated here that the loss from evaporation was 1.69 inches, it means that the amount of water evaporated would have been sufficient to cover the bottom of the can or the surface of the soil in it to the depth of one and sixty-nine one-hundredths inches.

THE MEANING OF THE EXPERIMENTS.

These figures show that during this period of rather dry, warm weather in summer, both soils lost more water when left with their surfaces compact than when they were stirred about as deep as is ordinarily done in hoeing and cultivating; and that the heavy, clayey soil lost more than the lighter, sandy loam. This means a great deal where crops are liable to suffer from summer drouth. Many accurate observations prove that in most regions the water that falls during the summer is not enough for the support of crops.

The earth serves as a reservoir for water which, falling at other times as well as while the crop is growing, is held to be used as the plants need it, just as a lamp serves as a reservoir for oil to supply the flame. Part of the water which comes in rain and snow flows over the surface of the soil to streams and the sea; part is evaporated before it penetrates to the lower strata of the soil; part forms the "ground water" which we find in digging wells, and which, until it slowly makes its way to springs and rivers, is kept in store for vegetation. In dry weather the ground water is continually rising to the upper layers of the soil where the roots of plants can use it. It is drawn up by capillary attraction or capillarity. In the words of Professor Storer:—

> "A dry surface soil, like an empty sponge, drinks up, absorbs, and actually lifts the water. * * * The particles of the soil and the pores of the soil above the ground water proper, suck up moisture from it precisely as a wick draws up oil in a lamp. * * * As Professor Johnson has said, just as the strands of wicking in a lamp must not fit too tightly or to loosely in the socket in order to the best capillary action, so in the soil there is a certain degree of porosity which is best suited to the lifting of water."

The force of capillarity which draws up the oil in the wick of the lamp, or causes water to spread through a cloth of which a corner is wet, or draws water from wetter to dryer soil, whether upwards or downwards, depends upon various factors. One of the chief is the size of the channels, the pores, through which the water passes. These must be extremely fine, but must not be stopped up. In common sands they are too coarse; in clay in which the particles are extremely minute, they often get clogged. Sandy soil is improved by admixture of clay, and clay by sand. Loams which contain both are generally the best soils. It is important that the pores or passages be of proper size, and that there be a continuous system of them. If they are too large, *i. e.*, if the particles of soil are too widely separated, the water will not pass through them as readily.

Stirring the soil loosens it, makes the pores larger, and breaks their continuity. It is easy to see, therefore, why water does not pass by capillarity through the surface of a soil that has been loosened by hoeing or cultivating as well as it does through one that has become compacted by long standing under the influence of rain and other agencies.

A compact layer at the top of the soil helps bring the water up to the surface, where the intense heat of the sun changes it to vapor and the wind carries it away. If the layer be loosened, the openings in it are enlarged and hold more air, which is a poor conductor of heat. It thus acts as a mulch and tends to keep the soil below cooler, and so helps to defend the water against the dissipating influences of sun and wind, as well as to keep it from coming to the surface where they act.

This brings us to the point. In dry weather, water escapes from the upper layers of the soil in two ways: (1) It is taken up by the roots of the plants and exhaled through the leaves, and (2) it evaporates from the surface, the evaporation being increased by sun and wind. The water which passes through the plant brings it sustenance, and is hence most useful to the farmer. That which evaporates from the soil is so much lost to him. When he hoes and cultivates the land on which his crops are growing, he permits nature to bring her stores of water to the roots of his plants, so that they may live and thrive upon it and upon the nutrient it brings, but prevents it from escaping into the air and being lost to them and him.

To come back to our experiments. Here are the results in simpler form:—

	WATER LOST.	
	From Heavy Soil.	From Light Soil.
Not stirred, - - - -	1.66 inches.	1.31 inches.
Stirred, - - - -	1.26 "	.70 "
Difference, - - -	.40 inches.	.61 inches.

During the sixteen days in August, although the weather was not particularly warm nor dry, the heavy soil lost four-tenths of an inch less water, and the light soil six-tenths less, by evaporation, when stirred at the surface than when not stirred.

The heavier, clayey loam lost more water than the sandy soil. This might seem to imply that the heavier soil would be worse in drouth, but experience proves the contrary, and it is easy to see why. The clayey loam, with its finer pores and more favorable chemical constitution, holds more of the water which falls in rain and draws more from the supply of ground water. In other words, it has more water than the light, sandy soil, and can lose more and still keep more for the plants.

Of course, hoeing and cultivating have other uses than to regulate the temperature of the soil and the evaporation of water.

They destroy weeds, which, if allowed to grow, would rob the crop of both plant food and water. When the surface of the soil is loosened, air and other gases penetrate more freely, and rain soaks into it more readily and less of it runs off from the surface of the field. But to discuss these and the many other bearings of the subject would be outside the present purpose.

RECAPITULATION.

The substance of the above statement may be summed up in a few words.

Of the resources the husbandman has to care for, one of the most precious is water. To husband this economically, to save that which comes in rain and snow, and to make it most useful in times of drouth, is an important part of successful farming.

The lesson which these experiments illustrate, and others explain more fully, is the value of surface tillage. It is not simply for the sake of killing weeds that the farmer hoes his corn. Weeds are his enemies, but drouth is worse; and the moisture is often insufficient for full yield even when no drouth is apparent. The soil has reserve stores of water for his crops, but in summer the supply gets low, and the same force of capillarity which brings it up to where the roots of his plants can get it, carries it past them to the surface, where the sun's heat changes it to vapor and winds bear it away. Hoeing and cultivating loosen the upper layer of the soil. The pores through which the water is drawn up are thus enlarged and the connection between them is broken; capillary action is consequently hindered and less water passes through. At the same time more air enters, and the loosened layer conducts less heat to the soil beneath. The loosened layer acts as a mulch, and tends to keep the soil below cooler while it prevents the water from reaching the surface, and thus, in a twofold manner, protects the rising moisture from evaporation. In this way the wise cultivator uses the forces of nature to bring water to the roots of his plants, and at the same time to prevent its passing by them and escaping into the air. The water is freighted with plant food,—part of it brought from below, part of it dissolved from the soil about the roots, and part derived from the air above. So the crops are nourished and the yield of the land increased.

Of course, the principle here involved has wider applications. A large part of the whole purpose of tillage is to regulate the supply of water as well as that of air and other gases, and of heat. Soils get too compact and need to be loosened; and hence we plough deep, and harrow to break up the clods. But at times they are too loose and need to be made more compact. We roll land after wheat is sown, and press the hoe down upon the earth with which we cover the corn in planting, so that the soil particles may be forced closer together and capillarity made to bring more of the needed moisture to the germinating seed.

The object of the Experiment Station is both to investigate and to teach. This account of a simple experiment is meant to serve as seed thought. If it is read and pondered by the fireside and discussed in the meetings the coming winter; if it thus helps to explain and to suggest things that farmers need to understand for their practical work, and which supply the food for the higher intellectual life as well, its object will be accomplished.

METEOROLOGICAL OBSERVATIONS.

The Meteorological Observations of the Station began June 1st, the outfit consisting of standard maximum, minimum, and wet and dry bulb thermometers; Green's pattern and the New England Meteorological Society's rain guages. A standard Signal Service barometer, and an anemometer, with an electrical recorder for recording the velocity of the wind, have since been added. The anemometer has not yet been brought into use, as the office of the Station has been but recently completed.

Observations of temperature, pressure, and state of the weather are taken tri-daily, at 7 A. M., 2 and 9 P. M. Monthly blanks, furnished by the New England Meteorological Society, are filled out at the close of each month, one copy being sent to the society and another put on file at the Station.

Early in June, standard rain guages of the New England Society and Signal Service patterns were forwarded to the gentlemen conducting field experiments in connection with the Station on their farms throughout the State. A careful record of the rainfall, in close proximity to the experiments, has been kept throughout the season. A summary of the observations follows.

Now that the Station is provided with a telephone, daily weather predictions are received from the Signal Station at New Haven.

SUMMARY FOR JUNE, JULY, AUGUST, SEPTEMBER.

OBSERVATIONS MADE AT MANSFIELD, BY E. A. BAILEY.

	JUNE.	JULY.	AUGUST.	SEPT.
Highest Barometer,	—	30.29	30.28	30.65
Lowest "	—	29.46	29.56	29.51
Mean "	—	30.00	29.97	30.07
Highest Temperature,	94.2	86.9	87.6	74.5
Lowest "	41.0	50.2	44.4	26.9
Mean "	65.3	66.4	67.3	57.1
Total Rainfall,	2.10	1.93	4.97	8.45
*No. of cloudy days,	3	4	6	10
No. of days with precipitation of .01 inches or more,	10	7	9	10

* Cloudy at each observation.

RAINFALL DURING JUNE, JULY, AUGUST, AND SEPTEMBER.

OBSERVATIONS MADE AT THIRTEEN LOCALITIES IN THE STATE.

LOCALITY.	OBSERVER.	RAINFALL IN INCHES.			
		June.	July.	Aug.	Sept.
Birmingham,	H. R. Stevens,	2.01	1.76	6.56	7.67
New Britain,	H. F. Wells,	1.27	2.01	4.66	7.95
Newington,	F. A. Kirkham,	1.20	1.75	4.91	8.31
West Simsbury,	S. T. Stockwell,	1.89	2.33	3.67	8.88
Durham,	H. S. Merwin,	*1.60	1.65	6.29	6.96
Middletown,	H. H. Hubbard,	2.04	1.45	6.74	7.47
Vernon Centre,	E. H. Lathrop,	1.01	2.03	—	7.85
Mansfield,	E. A. Bailey,	2.10	1.93	4.97	8.45
Pomfret,	W. J. Bartholomew,	*1.60	1.89	6.29	8.95
South Woodstock,	L. J. Wells,	—	1.51	4.19	9.17
North Woodstock,	L. H. Healey,	—	3.30	3.73	9.24
Brooklyn,	H. F. Cox,	*1.60	2.46	7.35	9.04
Clarks Falls, (North Stonington),	J. B. Perry,	1.05	1.91	7.72	9.62

* Observations began June 10.

GRASS AND FORAGE GARDEN.

In the Grass and Forage Garden on the farm of the Storrs School, a number of species and varieties of grasses, legumes, and other fodder plants have been sown, and sods have been set out. It is hoped that the number and kinds of plants may be greatly increased in the following years. The Station desires, with other things, to test not only the different grasses produced in Connecticut, including those found in old meadows and pastures in all parts of the State, but new grasses and forage plants as well.

Specimens of seeds have been furnished by the Department of Agriculture at Washington, by the Connecticut (New Haven) and Massachusetts Stations, and by private dealers.

The work in this direction was necessarily begun rather late in the spring, and some of the grasses have failed to mature. Another season this difficulty will be less felt. The following is a list of the plants grown during the past season:—

LIST OF PLANTS UNDER CULTIVATION IN THE GRASS AND FORAGE GARDEN.

Achillea millefolium.	Yarrow.
Agropyrum repens.	Couch-grass. Quack-grass.
Agrostis perennans.	Wood red-top.
Agrostis scabra.	Hair-grass. Thin grass.
Agrostis stolinifera.	Fiorin. Creeping bent-grass.
Agrostis vulgaris major.	Fall red-top.
Agrostis vulgaris minor.	Small red-top.
Aira flexuosa.	Hair-grass.
Alopecurus pratensis.	Meadow fox-tail grass.
Anthoxantum odoratum.	Sweet vernal grass. Sweet-scented spring grass.
Apera spicata venti.	Awned bent-grass.
Arrhenatherum (Avena) elatior.	Fall meadow oat-grass.
Avena flavescens flexuosa.	Yellow oat-grass.
Bromus brizaeformis.	Briza-like chess.
Bromus tectorum.	Brome-grass.
Bromus secalinus.	Cheat. Chess.
Bromus unioloides (Ceratochloa australis).	Australian brome-grass.
Cynosurus cristatus.	Crested dog-grass.
Dactylis glomerata.	Orchard-grass.
Deschampsia caespitosa.	Hair-grass.
Elymus Virginicus.	Wild rye-grass.
Eragrostis poeoides.	
Festuca duriuscula.	Hard stemmed fescue-grass.
Festuca fluitans.	Water fescue.
Festuca heterophylla.	Various leaved fescue-grass.
Festuca ovina.	Sheep's fescue-grass.
Festuca pratensis.	Meadow-fescue.
Festuca rubra.	Red fescue-grass.
Festuca tenella.	Small annual fescue-grass.
Festuca ovina tenuifolia.	Sheep's fescue-grass.
Hedsarum onobrychis.	Sainfoin.
Holcus lanatus.	Velvet-grass.
Lolium Italicum.	Italian rye-grass.

Lolium perenne.	Perennial rye-grass.
Lupinus Albus.	White lupine.
Lupinus hirsutus.	Blue lupine.
Medicago lupulina.	Black-seeded medick.
Medicago sativa.	Lucerne. Alfalfa.
Melilotus alba.	White melilotus. White sweet clover.
Melilotus caeruleus.	Blue sweet clover.
Ornithopus sativus.	Serradella.
Phalaris arundinaceae.	Reed canary-grass.
Poa compressa.	Wire-grass. English blue-grass.
Poa nemoralis.	Woods spear-grass.
Poa serotina.	Fowl meadow-grass.
Poa trivialis.	Rough-stalked meadow-grass.
Trifolium hybridum.	Alsike clover.
Trifolium incarnatum.	French clover.
Trifolium pratense.	Common red clover.
Trifolium repens.	White clover.
Vicia sativa.	Spring vetch.
Vicia faba.	Horse bean.

Thanks are due to Dr. George Vasey of the U. S. Department of Agriculture, for revision of the names in the above list.

W. O. ATWATER, DIRECTOR.

STORRS SCHOOL

Agricultural Experiment Station,

MANSFIELD, CONN.

(P. O. STORRS, TOLLAND CO., CONN.)

BULLETIN No. 3. FEBRUARY, 1889.

ROOTS OF PLANTS AS MANURE.

The value of the plant-food in the soil and the most economical ways to utilize it, are too little understood. Farmers take pains to save the manure made on the farm, which is, of course, the wisest possible thing to do. They buy commercial fertilizers, potash salts, super-phosphate, bone, nitrate of soda and the like, to furnish plant-food for their crops, and pay from five to twenty cents or more a pound for the potash, phosphoric acid, and nitrogen contained in them. This is also wise, if the materials furnish in economical forms the nutritive ingredients which the crops require and the soil cannot supply. But one most important part of good farming is to husband the resources of the farm. One of these resources is found in the roots and stubble of plants. The value of these as manure is generally underrated. The roots of growing grass, corn, and other plants serve to support the plants and gather food and water for them from the soil. When the crop is harvested, the roots and stubble remain behind to manure the land for succeeding crops. How much of this manurial matter is left by different crops, and how much of the valuable fertilizing ingredients does it contain?

These questions are difficult to answer, because the exact information is rather hard to get, and comparatively few accurate tests have been made. The amount and composition of the roots of plants of even the same kind differ greatly with the differences of soil, culture and other conditions. But the few observations that have been made bring useful information and help us to understand why rotation of crops is so important.

OBSERVATIONS ON THE ROOTS OF GRASS, CLOVER, ETC.

During the past season the Station conducted a series of observations upon the quantity and fertilizing value of the roots and stubble of cow peas, timothy, redtop, and buckwheat. In the years 1875-7, the Director then in charge of the Middletown Station instituted as a part of the early work of the latter, a series of observations with clover, timothy, wheat, and other plants, the results of which were given in the Report of the Station for 1877-8.*

The method of making these observations consisted in separating the stubble and roots as carefully as practicable, and weighing and analyzing them. The samples were obtained from portions of the field representing, as nearly as could be determined, an average condition of the crop grown.

After removing weeds and other foreign matter, a trench about two feet deep and large enough for convenience in working, was dug on all sides of a small section of earth, leaving a square block of soil in the centre a little more than two feet on each side. The sides of this block were carefully trimmed until it was exactly two feet square, thus making an area of four square feet or 1-10890 of an acre.

By means of a cord tightly drawn around the block, sections six inches in depth were marked off, and the earth from each layer removed and placed in a box by itself. The trench was deepened as required for convenience in working as the layers were removed. In the earlier experiments by Prof. Atwater above referred to, practically the same method was employed, except the sections examined were one foot by two instead of two feet square.

Each section of earth was worked over separately by hand labor, the roots, stubble (and in case of grass, the new growth), being separated from the soil and, as far as possible, from the roots of weeds. In spite of the greatest care the separation is not perfect; minute fragments of roots remain in the soil and fine particles of earth adhere to the roots, but the roots left behind represent so small a portion of the whole, that the results could not have thus been materially affected. On the whole, the method of obtaining the samples and separating the roots, although laborious and time-consuming, was quite satisfactory. Had water been used to wash away the earth, a much larger portion of the finer roots would have been lost.

The subjoined statements, from a more detailed account of these experiments to be published in the forthcoming Annual Report of the Station, will give an idea of the quantities of stubble and roots of cow peas, timothy and redtop, and buckwheat at different depths.

Specimen M. 29. Cow peas, stubble and roots. From the farm of the Storrs School. Surface soil to a depth of about 7 inches, light loam. Subsoil, yellow and compact, becoming at a depth of 30 inches, loose and gravelly in texture. The specimen consisted of stubble and such roots as could be pulled out of the soil with the stubble, and included nearly all of the larger roots of the surface soil. This specimen is from three sections of 4 square feet each, from a portion of the field which yielded 15,840 lbs. of green crop per acre. Crop harvested September 27 and 28. Specimen taken October 3. Weight of roots and stubble after partial drying in the laboratory, 93 grams. This amount from 12 square feet, corresponds to 558 lbs. per acre.

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* Report of Connecticut Board of Agriculture for 1878, page 335 et seq.

Specimen M. 30. Cow peas, stubble and roots. From same field as M. 29. When received at laboratory, after freeing from soil as far as possible, the weight of the stubble and roots from different depths in an area of 4 square feet corresponded to the following number of pounds per acre:

Stubble and first six inches of roots,	912.3 lbs.
Second six inches of roots (6 to 12 in. deep),	44.9 lbs.
Third six inches of roots (12 to 18 in. deep),	54.0 lbs.
Fourth six inches of roots (18 to 24 in. deep),	34.3 lbs.
Fifth six inches of roots (24 to 30 in. deep),	62.9 lbs.
Sixth six inches of roots (30 to 36 in. deep),	59.3 lbs.
Seventh six inches of roots (36 to 42 in. deep),	40.1 lbs.
Stubble and roots to depth of 42 inches,	1207.8 lbs.

Specimen M. 32. Timothy and redtop, stubble with roots from first six inches. Soil the same as M. 29. Specimen from an area of 4 square feet, was obtained November 7th. The field was mowed July 23d, and yielded about two tons of hay per acre. The field contained besides the roots and stubble, the rowen or second growth, which was about three inches high and was green and luxuriant at the time sample was taken. The crop was principally timothy with a slight admixture of redtop. The weight of stubble (including "rowen") and roots from first six inches, after drying in the laboratory, was equivalent to 7944 lbs. per acre.

Specimen M. 33. Timothy and redtop, roots. Specimen consisting of roots below a depth of six inches was taken from the same block of soil as M. 32 and at the same time. The weight of the roots from different depths as received at the laboratory corresponded to the following number of pounds per acre:

Roots from second six inches (6 to 12 in. deep),	360.1 lbs.
Roots from third six inches (12 to 18 in. deep),	216.1 lbs.
Roots from fourth six inches (18 to 24 in. deep),	72.0 lbs.
Roots from fifth six inches (24 to 30 in. deep),	24.0 lbs.
Roots from sixth six inches (30 to 36 in. deep),	6.0 lbs.
Roots from depth of 6 inches to 36 inches,	678.2 lbs.
Total roots and stubble, including rowen,	8622.2 lbs.

Specimen M. 34. Buckwheat, stubble and roots. Surface soil a compact clay loam with rather more than an average amount of vegetable matter. Subsoil, clayey; compact and moist. Buckwheat cut September 24th. Specimen taken September 29th from an area of 4 square feet. The weight of roots and stubble as received corresponded to the following number of pounds per acre:

Stubble and first six inches of roots,	503.2 lbs.
Second six inches of roots (6 to 12 in. deep),	20.4 lbs.
Total weight of stubble and roots,	523.6 lbs.

The third six inches was nearly free from roots.

It is clear that while the roots penetrated quite deep in the soil, the larger portions were in the surface soil and the weights decrease rapidly in the subsoil. In the cow pea here observed this did not appear to be the case to the same extent. While here as with the others the most of the roots were in the surface soil, as large a weight of roots was found in a section at a depth of four feet as in a section of the same size at the depth of six inches; and as the roots came to the laboratory, those from a depth of four feet were as large in size as those from near the surface. If this large root growth at such a depth is characteristic of the cow pea and allied species, it will help to explain their remarkable feeding capacity and their ability to obtain supplies of food at depths beyond the reach of most other plants.

The following figures from the earlier experiments referred to give the quantities of roots found at different depths. By surface soil is to be understood the layer which showed in its appearance the effects of tillage, and action of air and frost.

Weight of Roots and Stubble in One Acre.

KIND OF PLANT AND STAGE OF GROWTH.	Depth of Surface Soil.	Weight of Roots of Surface Soil.	Weight of Roots of Subsoil.	Weight of Stubble.	Weight of Roots and Stubble.	Weight of Tops (Crop).
Clover. In full blossom, - -	8	850	48	—	—	1657
Clover. Ripe, - - - - -	—	1388	72	1272	2732	—
Wheat. Just before heading, -	8	533	58	226	817	2554
Wheat. Just before blossoming, -	8	480	322	394	1196	4489
Wheat. Seed in milk, - - -	12	691	43	418	1152	5411
Wheat. Seed ripe, - - -	12	591	125	595	131	7092
Oats, - - - - - - -	—	245	48	216	509	5037
Barley. Just before heading, -	12	370	38	187	595	2449
Barley. Commencing to blossom,	12	403	19	408	830	3937
Barley. Seed in milk, - - -	12	437	34	509	980	4907
Barley. Seed ripe, - - -	12	293	43	355	691	7154
Hungarian, - - - - - -	—	648	72	341	1061	6199
Timothy. In full blossom, - -	11	855	—	—	—	4249
Timothy. Ripe, - - - - -	17	2502	14	—	—	5027
Timothy. Ripe, - - - - -	15	5210	5	2056	7271	5254
Timothy. From meadow, - -	—	2002	58	3102	5162	—
Native Grasses. Pasture, - -	—	3087	48	2166	5301	—
Native Grasses. Meadow, - -	—	4110	82	3462	7654	—

FERTILIZING MATERIALS IN ROOTS.

But the manurial value of the roots depends upon their composition as well as their quantity. The most valuable ingredients are nitrogen, phosphoric acid, and potash. The following gives the weights of roots (or roots and stubble), and of these ingredients per acre in the experiments named, and with them corresponding results of observations made by Dr. Voelker in England and Dr. Weiske in Germany.

Amount of Roots and Stubble and Valuable Ingredients left in one Acre, with Valuable Ingredients in Manures.

KIND OF PLANT AND PORTION ANALYZED.	Roots and Stubble	Nitrogen.	Phosphoric Acid.	Potash.
Reported herewith.	LBS. Water free	LBS.	LBS.	LBS.
Cow peas. Stubble and roots to depth of 6 in.,	711	10.0	2.7	5.3
Cow peas, Stubble and roots to depth of 3½ ft.,	1095	14.5	2.8	6.4
Timothy and redtop. Stubble and roots to depth of 6 in., - - - - - - - -	7606	83.7	23.8	53.5
Timothy and redtop. Roots below 6 in. to depth of 3 feet, - - - - - - - -	617	6.4	1.4	2.3
Timothy and redtop. Stubble and total roots to depth of 3 feet, - - - - - -	8223	90.1	25.2	55.8
Buckwheat. Stubble and roots to depth of 1 foot,	483	4.4	1.3	3.8
Middletown Station (W. O. Atwater).				
Timothy. Roots, - - - - - - -	2240	31.1	7.0	8.4
Wheat. Roots, - - - - - - -	658	6.4	1.5	2.6
Clover. Roots, - - - - - - -	1335	35.5	10.0	15.0
Dr. Voelker, England.				
"Good Clover." First year. Roots, - -	4155	100.0	—	—
"Bad Clover." First year. Roots, - -	1550	31.0	—	—
"Thin Clover." Second year. Roots, - -	7026	66.0	29.5	—
"Good Clover." Second year. Roots, - -	6503	65.0	27.0	—
Clover. First year. Mown twice. Roots, -	1493	24.5	—	—
Clover. First year. Mown once. Roots, -	3622	51.5	—	—
Dr. Weiske, Germany.	Air dry			
Rye. Roots and Stubble, - - - - -	3400	62.0	24.0	30.0
Barley. Roots and Stubble, - - - -	1515	22.0	11.0	9.0
Oats. Roots and Stubble, - - - -	2200	25.0	28.0	24.0
Wheat. Roots and Stubble, - - - -	2240	22.0	11.0	17.0
Red clover. Roots and Stubble, - - -	6580	180.0	71.0	77.0
Buckwheat. Roots and Stubble, - - -	1630	45.0	10.0	9.0
Pease. Roots and Stubble, - - - -	2400	53.0	14.0	11.0
Lupine. Roots and Stubble, - - - -	2800	58.0	13.0	16.0
Fertilizers.	Fertilizers. LBS.			
Rich stable manure, - - - - -	2000	10	10	8
Nitrate of soda, - - - - - -	100	16	—	—
Dissolved bone black, - - - - -	100	—	16	—
Ground bone,* - - - - - -	100	3	22	—
Muriate of potash, - - - - - -	100	—	—	50

*Analyses taken from Farmers' Annual, 1882. Jenkins and Armsby.

When the stubble is turned under, both it and the roots decompose and their manurial ingredients become more or less speedily and completely available for succeeding crops. The crop that leaves a large amount of these materials in and upon the soil after harvesting adds much to the next year's store of plant-food and hence to the fertility of the soil.

In the few cases in which the stubble was weighed it was nearly as much as the roots of the first six inches of the soil. Of course the amount of stubble would vary much with the manner of harvesting the crop. In the case of such plants as grass, a new growth starts after the crop is removed and increases with the length of time between harvesting and ploughing under.

As might be expected, the amount of roots and stubble vary with different crops and even with the same kind of crop under different circumstances. The ratio between the amounts of roots and of tops is extremely variable, still it is safe to say in general that the greater the amount of the crop of a given plant the greater will be the amount of roots and stubble left behind. But a small crop of one plant, as clover, may leave more fertilizing material in the soil than a large one of another plant like wheat. These facts, together with the small amount of roots worked upon, tend to make uncertain many lessons that might be drawn from these tables (indeed perhaps the most important fact here brought out is the need of more observations), still certain general conclusions must be true.

Clover roots and stubble contain large percentages of all three of the most valuable ingredients of plant-food, and as clover leaves a large amount of roots and stubble in and upon the soil, it adds greatly to the store of fertilizing material for future use. As will be seen from the table, Dr. Weiske found a little over three tons of stubble and roots per acre remaining from a crop of clover. This contained 180 lbs. of nitrogen, 71 lbs. phosphoric acid, and 77 lbs. of potash. From the composition of fertilizers as given in the above table, it would require over 1,100 lbs. of nitrate of soda, 400 lbs. of dissolved bone black, and 150 lbs. of muriate of potash to furnish the same amount of fertilizing materials. It should be borne in mind, however, that in such fertilizers as nitrate of soda and superphosphate the plant-food is ready for use at once. In roots and stubble, as in stable manure, chemical changes are first needed to make the ingredients available to the plants that feed on them. Hence a pound of nitrogen may be worth more in nitrate of soda than in roots or stable manure, because it brings a quicker return in the crop.

While the cow pea in these experiments did not leave as much per acre as the clover, yet it furnishes a very considerable amount of valuable manure. The crop from which these samples were taken was small, and probably in most cases more plant-food would be left for the next crop than this experiment would indicate.

The timothy stubble and roots together, while not having as large percentages of the valuable ingredients of plant-food as clover, yet with the great amount of stubble and new growth that is plowed under yields a great deal of manurial matter. This may explain why crops do so well when planted upon turf. An illustration occurred in one of the field experiments conducted for the Station during last season. The field selected for the experiment was covered with a heavy sod at the time of plowing. The plots to which no manure was applied yielded at the rate of over fifty bushels of shelled corn to the acre. Part of the plant-food that made this possible came from previous manuring, but doubtless a great deal of it was supplied by the roots and stubble.

So far as it is safe to judge from the figures contained in the table, wheat, oats, and buckwheat leave much less plant-food in the soil than the other crops. Probably the grain crops as a class are of comparatively little value in enriching the soil for following crops.

Clover, cow peas and other legumes have a peculiar power of gathering plant-food and especially nitrogen from natural sources. Although they contain much more nitrogen than wheat, oats, and similar grains, they thrive and bring large yields where wheat will not. While their especial faculty for gathering nitrogen from the stores in the soil and probably from the air is not yet explained, the important fact here is that they do gather it and leave a great deal of it in the roots and stubble. Nitrogen is the costliest ingredient of fertilizers. These facts help to explain the economy of clover for manure and why clover is so valuable as a preparatory crop for wheat and other grains.

The above cited facts would seem to imply that the legumes, such as clover are especially valuable for this kind of manuring; that timothy and other grasses stand next; and that the grain crops leave the least amounts of plant-food in roots and stubble.

METEOROLOGICAL OBSERVATIONS.

Observations of temperature, pressure, and state of the weather are made at the Station three times each day, viz.: at 7 A. M. and 2 and 9 P. M.

October, November, and December have, with two exceptions, November 25th and December 14th, been very mild. The total rain-fall was above the average. In October, 45 out of 93 observations, and in November, 41 out of 90 were rainy or cloudy.

SUMMARY FOR OCTOBER, NOVEMBER, DECEMBER, 1888.

Observations made at Mansfield, by E. A. Bailey.

	Oct.	Nov.	Dec.
Highest Barometer, - - - - - - -	30.50	30.86	30.49
Lowest Barometer, - - - - - - -	29.47	29.39	29.24
Mean Barometer, - - - - - - -	29.95	30.12	30.01
Highest Temperature, - - - - - -	65.4	69.0	56.9
Lowest Temperature, - - - - - -	26.5	8.9	1.5
Mean Temperature, - - - - - - -	43.8	39.7	30.0
Total Precipitation, - - - - - - -	6.35	4.94	5.28
Number of days of precipitation of .01 in. or more,	15	13	6
*Number of cloudy days, - - - - - -	7	11	6
†Number of clear days, - - - - - -	5	12	7

*Cloudy at each observation. †Clear at each observation.

In accordance with the wish of the Station, copies of the publications will be mailed to all citizens of Connecticut and to Granges, Farmers' Clubs, and other agricultural organizations, who ask for them, and so far as circumstances permit, to those who apply from other States. Requests for publications and business communications should be addressed to

STORRS SCHOOL AGRICULTURAL EXPERIMENT STATION,
STORRS, CONN.

C. S. PHELPS, VICE DIRECTOR.
C. D. WOODS, CHEMIST.

STORRS SCHOOL
Agricultural Experiment Station,
MANSFIELD, CONN.

(P. O. STORRS, TOLLAND CO., CONN.)

BULLETIN No. 4. JULY, 1889.

METEOROLOGICAL OBSERVATIONS.

Observations of temperature, pressure, and state of the weather are made at the Station three times each day, viz.: at 7 A. M. and 2 and 9 P. M.

SUMMARY, JAN. 1ST TO JUNE 30TH, 1889.

Observations made at Mansfield, by E. A. Bailey.

	JAN.	FEB.	MAR.	APRIL.	MAY.	JUNE.
Highest Barometer, - - -	30.56	30.80	30.41	30.41	30.31	30.42
Lowest Barometer, - - -	29.28	29.57	29.15	29.46	29.70	29.58
Mean Barometer, - - -	30.01	30.10	29.87	29.97	29.97	30.01
Highest Temperature, - -	56.8	48.9	59.8	68.2	—	86.4
Lowest Temperature, - -	4.9	-6.5	17.0	26.0	32.0	40.9
Mean Temperature, - - -	30.8	22.1	34.9	45.6	58.4	65.2
Relative Humidity, - - -	—	—	—	—	75.2	81.9
Total Precipitation, - - -	4.03	1.64	1.96	3.49	2.16	3.50
No. of days with precipitation of .01 inches or more, - -	10	12	10	12	8	10
No. of clear observations, -	52	47	36	38	53	43
No. of cloudy observations, -	36	33	47	40	37	38

During the past year investigations on the bacteria of milk have been carried on in the laboratory of the Station, under the direction of H. W. Conn, Professor of Biology in Wesleyan University. The following is a brief summary of some of the more interesting results of this work:

BACTERIA IN MILK AND ITS PRODUCTS.

By H. W. Conn, Ph. D.

The term bacteria is used to comprise a class of organisms found abundantly in the air, water, and soil, and in plants and animals. As commonly employed, the term includes a large variety of organisms, which naturalists divide into the three classes, bacteria, yeasts, and moulds. The term microbe has been recently introduced to cover this same ground, and is for many reasons preferable. The plants included under this head are exceedingly numerous, and the part they play in nature is of great importance. They multiply with the greatest rapidity,—a single individual in the course of a few days being able to give rise to millions. While they are thus growing and multiplying they produce great changes in the medium in which they grow. All fermentation, such as raising of bread, fermenting of beer, cider, etc., putrefaction and decay, such as rotting of potatoes, decay of wood, etc., are produced by the organisms here included. They are of immense value as well as injury. Through their agency dead animal and vegetable matter is decomposed and prepared to be incorporated with the soil and to be used as food by plants. It is doubtful if vegetable life could be long continued without their aid. On the other hand, they cause disease in plants and disease in animals; many of the most dangerous diseases, as cholera, typhoid fever, consumption, hog cholera, bovine tuberculosis, chicken cholera, etc., being produced by these disease germs. These organisms are extremely minute and simple. They are commonly not more than 1-2000 of an inch in length. In shape they show three chief varieties, which may be compared to a lead pencil, a ball, and a cork-screw. To-day they are universally regarded as plants, in spite of the fact that many of them are endowed with motion.

METHODS OF EXPERIMENT.

The method of our experiments has been that common in modern bacteriological research. For culture solutions the ordinary beef peptone solution, stiffened by gelatin, or more commonly by agar-agar, has been used. For most of our experiments with cream, "ripened cream" has served as a starting point. In some cases sweet cream has been ripened in the laboratory and examined each day, but more commonly specimens of ripened cream have been obtained from the dairy of a butter-maker and directly studied. Plate cultures have been made from the cream, usually with agar-agar, since the organisms found grow in this medium most readily. From the various colonies found in the agar plates, needle cultures have been made in gelatin. Subsequent purification of the organisms has been made in the ordinary way, by transferring from tube to plate and plate to tube until the bacteria were separated from each other in pure cultures.

For further experiment, milk has been sterilized in test tubes, This can be done at a temperature of about 70° c., but it has been found more convenient to put the tubes for a few minutes in a steam sterilizer. Sterilization upon three successive days is commonly sufficient, but in a few cases milk was found to change even after such treatment. The sterilization of cream has been accomplished in the same way. There is more difficulty in this, however, for the cream is apt to form a thick layer on the surface with a thin watery layer below, and this occurs even in cream that is thoroughly sterilized. In our experiments upon the action of the different bacteria upon milk, the inoculations have been made and the tubes allowed to remain at the temperature of the laboratory for a day or two. If no change occurs, they are then placed in a thermostat at a temperature between 30° c. and 35° c., and allowed to stay there till they have produced their effect upon the milk.

Accompanying all of the experiments upon milk and cream, we have carried on a series of experiments with the same organisms upon three different solutions. One was the ordinary beef peptone solution without gelatin; the second the same solution, to which a small amount of milk-sugar had been added; and the third the beef peptone solution, with the addition of glucose instead of milk-sugar.

Inasmuch as it has been our object to determine the general effect upon milk and its products of the various bacteria present in the air, it has been necessary to work with all the numerous species that have been found in ripened cream. This has necessitated a very large number of experiments, continuing through eight months. The account of these experiments, which to be in any way useful will require a large number of pages of detailed description of individual species of bacteria, as well as their action and effects, are reserved for the next Annual Report of the Station. The present paper is designed to give only a brief summary of the most important facts concerning the relation of bacteria to milk and its products. For this reason the following pages include results of the work done here, and of other investigators as well, and some conclusions derived from them.

BACTERIA IN MILK, CREAM, AND BUTTER.

Milk is a medium in which bacteria grow with the greatest readiness. Our experiments have thus far given indication of some thirty or forty species of bacteria that are floating in the air in this vicinity, every one of which is found in cream, and grows with the greatest facility in milk. Probably none of those which we have studied produce disease, and hence are called non-pathogenic. The researches of others have shown that many of the disease (pathogenic) germs also find in milk a favorable medium for growth. According to our experiments, cream seems to be even a better medium for the growth of bacteria than milk, for it will keep longer without putrefying, and thus allow some of the slower growing species to develop. Butter is not a good medium for the growth of bacteria, apparently because they require for their development a certain amount of albuminous material of which good butter, being mostly fat, contains only a minute amount. We have, however, always found bacteria present even in the sweetest of butter, but usually in small numbers. When for any reason they become very numerous, the butter becomes tainted.

If milk, cream, or butter is kept free from bacteria, the ordinary changes do not take place in them. For example: the bacteria in milk can be readily killed by heating the milk to a boiling or even lower temperature for a few moments upon three successive days, and then bacteria being excluded, the milk is found to keep sweet indefinitely. Killing the bacteria by heat is known as sterilizing. If we thus sterilize a lot of milk, and then put into it a few of any particular species of bacteria, we can very easily determine the effect which this species produces upon the milk. It is in this way that our experiments have been made.

Milk and cream under ordinary conditions cannot be kept free from bacteria. Milk drawn from a healthy cow is free from them, but they may get into it when the milk is in contact with the air during milking. A single experiment will indicate the difficulty of keeping them out of milk. Eight test tubes were washed perfectly clean and plugged with a mass of cotton. They were then heated very hot until all living matter in them was killed. These were taken into a milking yard, and after the teats of the cow and the hands of the milker had been carefully washed, the cotton plug was taken out and milk drawn directly from the cow into the tubes, and the cotton plug replaced. Of these eight tubes, seven soured in a few days and many bacteria were found in them. The other remained sweet for a long time, but eventually it also changed. From this experiment it is seen that in the few seconds in which it was exposed to the air the milk was contaminated with bacteria. A very common source of contamination of milk is from vessels in which the milk is placed. These, unless recently washed in boiling water, contain bacteria clinging to their walls. These bacteria begin to grow as soon as the milk gets into the vessels, and in a few hours will multiply so as to be extremely abundant.

NUMBER OF BACTERIA IN MILK. DIFFERENT SPECIES.

The number of bacteria in milk will depend chiefly on three things: 1. The cleanliness of the vessels. 2. The temperature of the milk, warmth being favorable to their growth. 3. The length of time that the milk has been standing. Ordinarily the number of bacteria in the air is of comparatively little importance, unclean vessels being the great source of contamination. If however, the vessels are perfectly clean, the number of organisms in the air becomes the important factor. In cream which has been allowed to "ripen" for a few days, the number is extremely great. In the specimens of ripened cream which we have examined, from 10,000 to 100,000 individuals have been found in a single drop, the latter number being usually nearer the truth than the former. Even under conditions most unfavorable for their growth, in a cool cellar during the winter, 12,000 have been found in a single drop. These are capable of multiplying with the greatest rapidity, producing hundreds of thousands in a few days.

Not only is the number of individuals very great, but the number of different species is considerable. Some thirty or more different species of bacteria have been found during the winter in specimens examined in our laboratory. No single specimen of cream contained them all, but each contained several species.

The number of bacteria present has, however, no significance until we know something of their effect. Some are harmless, some are hurtful; some affect cream, milk, and butter injuriously, and others do not. The effect produced by most of these organisms upon milk is striking.

Of the large number of organisms found in milk, two or three seem to be characteristic. The first is the one that produces the ordinary souring of milk, *(Bacillus acidi lactici)*. This organism upon being introduced into sterilized milk, grows rapidly and soon breaks up the milk sugar that is present into either lactic or acetic acid and carbonic acid. The acid thus formed causes the milk both to curdle, by hardening or coagulating its albuminous matter, and to acquire its well-known sour taste and odor. This organism is very abundant in the air in warm weather, but in the winter seems to be much less abundant. Indeed, it can at times almost be said to be absent. We have kept milk in an open dish in our laboratory, during cold weather, for two weeks without its going through the characteristic changes of souring. It finally curdled, but with a peculiar odor of decay, and did not sour in the typical manner at all. The vessel in this case was absolutely clean, so that the air was the only source of contamination. The changes which did take place were produced by bacteria other than the common sour-milk bacterium, this one not seeming to be present at all. The fact that the typical souring was thus prevented shows that the common sour-milk bacterium was not present in the air at the time, at least in any great quantity. Such an experiment would not succeed in the summer.

A second species almost always found in milk is *Oidium lactis*. This produces no important change in milk. It grows rapidly, but does not cause the milk to sour or curdle. Besides the two mentioned, a large number of other species have marked effects upon milk.

ACTION OF DIFFERENT KINDS OF BACTERIA IN MILK.

As concerns their action, we may divide them into four classes:

1. Some, like the bacteria of sour milk, cause the milk to sour by breaking up the milk-sugar into lactic or acetic acid and carbonic acid; curdling of the milk results. 2. Many produce the same result but only at somewhat higher temperatures. At ordinary temperatures they grow but do not curdle the milk; in a warm oven, however, the milk will soon curdle. Accordingly, these would sour and curdle the milk in summer, but would not do so, or would do so less readily, in winter. The temperature and time required to produce the curdling differ with different species of bacteria. 3. Some do not have the power of breaking up milk-sugar, do not produce any acid, and do not coagulate the milk. The milk remains liquid, and sometimes becomes decidedly alkaline. 4. A few species curdle the milk, but produce no acid, the milk becoming alkaline instead. The majority of bacteria of milk and cream which we have experimented upon produce a souring and curdling of milk at some temperature. Our experiments have also indicated that the action in all these species is somewhat similar,—*i. e.*, the breaking up of the milk-sugar into an acid and some other product. But although the action is thus fundamentally the same, the details of the action vary with each different species of bacteria.

The curdling is very different in character with different species. In some cases a hard curd and a clear liquid are formed; in others a curd is formed, but no liquid is separated from it; in still other cases the whole milk is turned into a semi-gelatinous mass. Sometimes the curd is easily broken or cracked like the curd of common milk; in other cases it is very tenacious, sticky, and slimy. Sometimes the curd is dissolved in a few days and the milk is left as a clear and almost transparent liquid. Here the casein seems to undergo a change similar to digestion, *i. e.*, conversion into peptones.*

In connection with the curdling there also arises in all cases a characteristic odor, which differs with different species of bacteria. There is a sour smell, a smell like sour bread, a smell like soft-soap, like salt mackerel, like a pig-pen, like the barn-yard, and in many cases a smell of putrefaction. Besides these there are others that cannot be described because of the lack of words in our language to distinguish odors. As far as our studies have gone, the effect of each species of bacteria upon the milk seems to be different from all others. The dairyman or the housewife would in most cases say that the milk had soured, but careful study shows that in reality the different bacteria do produce effects differing to a greater or less extent. The results of our experiments seem to indicate that what is commonly known as the souring of milk is not always caused by the common sour-milk bacterium, as has been usually supposed, but is frequently produced by others, and that the products formed are different. Particularly is this true in winter.

BACTERIA IN CREAM.

Our experiments were undertaken in the expectation that the so-called "ripening" of cream would prove to be a definite change due to the growth of bacteria. Having found that the souring of milk is less simple than had been supposed, we are prepared to find that the "ripening" of cream is also a complex process. It is not easy to say just what is meant by "ripened" cream. In ordinary farm practice cream is usually allowed to stand for a few days before churning, when it becomes somewhat thickened and acquires a pleasantly sour odor. In our creameries the cream is also ripened, though for a shorter time, and it does not become so thick or so sour. That the ripening is due to the growth of bacteria there can be no doubt. Ripened cream always contains these organisms in almost inconceivable abundance. In some places the ripening is hastened by adding a little sour cream as a "starter." This simply means the addition of a large number of bacteria, which of course hastens the process. Sometimes an artificial starter in the form of an acid is added. This practice proceeds upon the supposition that the ripening is due to the formation of an acid, which is probably a secondary matter. It is doubtful if this kind of a starter has any definite value.

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*Loeffler, Ueber Bacterien in der Milch, Berlin, Klinisch, Woch., 18, 1887.

By successive heatings, specimens of cream have been deprived of all bacteria, and it is then found that the cream remains unchanged indefinitely. In these specimens of sterilized cream we have planted the various species of bacteria that we have experimented upon. All of them grow well in the cream, and each has its characteristic effect, but no one of them has yet been found to produce exactly what we feel justified in calling ripened cream. Some curdle it; some cause it to putrefy. From all of our experiments we conclude that the ripening of cream is a complex matter. The souring is apparently due to a process similar to the souring of milk: the thickening in part to the curdling of the small amount of milk left with the cream, and in part to immense numbers of bacteria that develop. Another important factor in the ripening of cream is the decomposition of the albuminous matter present. In general we infer that different kinds of bacria assist in the ripening of cream, but doubt whether any one has such a definite relation to it as the sour-milk bacterium has to the curdling of milk.

OBJECTS OF THE RIPENING OF CREAM.

There seem to be two chief objects in ripening cream. It is a matter of experience that the butter will separate more readily from ripened cream, and the churning therefore be easier. And it is believed by many that the butter made from ripened cream will keep longer than butter made from sweet cream. A simple explanation is suggested, if not warranted, by the facts at hand, and may be of interest to butter-makers. Dr. Babcock of the Wisconsin Agricultural Experiment Station, has pointed out* that shortly after milk is drawn from the cow there appears in it a fine, inappreciable network of fibers, which produce in the milk a slight thickening somewhat like the clotting of blood, except that it is much less marked. This, which Babcock calls "fibrin," is of an albuminous nature and will readily putrefy. When the cream rises to the surface of the milk, a considerable quantity of this so-called fibrin is entangled with it and is skimmed off with the cream. The butter globules are enclosed in this fibrin, and in churning they must be shaken out. Now, in the time that the cream is ripening the numerous bacteria are at work upon this albuminous fibrin, feeding upon it and decomposing it. The breaking down of the fibrin is also assisted by the acid that is formed by the bacteria, for it is a well-known fact that acid will greatly assist in the solution of materials similar to this fibrin. After the fibrin is thus partly dissolved by the action of the bacteria, the butter globules will much more readily be shaken free from them and churning be made easier.

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*Agr. Exp. Sta. of Wis. Bull. No. 18.

The keeping property of the butter is easily explained by the same considerations. There is no doubt that bacteria are the cause of rancidity in butter. Bacteria cannot live upon pure fat, but require for food a certain amount of albuminous matter. It follows that the more albuminous matter there is in the butter, the more readily will they grow and the quicker will the butter become bad. If the cream is churned before the albuminous fibrin has become decomposed, the butter will usually contain more of the fibrin than will butter made from cream after the fibrin has decomposed. Butter made from ripened cream will naturally contain more bacteria than that made from sweet, since the ripened cream itself contains them, but this is a matter of less importance than the ability of the bacteria to grow and multiply in the butter, and for reasons above stated this they can more readily do in butter made from sweet cream.

From this it would seem that the value of ripening cream depends upon the albuminous fibrin that is present in the cream, and any process that diminishes this diminishes the necessity of ripening, at least so far as concerns the two objects above mentioned. Babcock has shown that the quicker the cream rises the less will be the amount of the fibrin entangled with it, and that when cream is separated by a centrifugal machine, a considerable part of the fibrin collects on the drum of the machine and less in the cream. It would seem therefore that there would be less need of ripening centrifugal cream than that raised in the more common way.

A third object attained by ripening cream is to give a certain flavor to the butter which is not obtained in butter made from sweet cream. This is a matter of as much importance to butter makers as either of the other two, for the value of butter usually depends more upon its taste than upon its keeping properties. But the relation of the taste of butter to the ripening of the cream, and to the method of handling the butter, is a matter too vague and indefinite at present to warrant definite statements.

CLEANLINESS IN DAIRYING.

It must be remembered that many bacteria are so minute that thousands of them might occupy less space than the point of a needle; that they multiply so rapidly that millions may be produced in a short time from a single one; that organic (animal and vegetable) matters, including many forms of what are ordinarily called dirt, are media for them to grow in; that milk is especially adapted to their development, and the most minute quantities of it may serve for their dwelling place and furnish food for their rapid growth; and that they are sure to adhere to the surface or cling in the joints of vessels that have contained milk. Bearing all of these facts in mind, the necessity for thorough cleansing of all vessels used in handling milk is apparent. To wash such vessels so that no particles of dirt will remain on the surface or in the joints is extremely difficult. It has been frequently demonstrated that no amount of washing in cold or even warm water will remove all bacteria. It is necessary to use *boiling* water and to leave it in the vessels for a considerable time to destroy the active forms of bacteria that are sure to be present. Even though the active forms may be killed by boiling water in the course of a few minutes, their spores, which correspond to seeds, will resist boiling temperature for a long time. The danger of contamination from spores is not so great but that it may be neglected for all practical purposes, and unless the vessels are contaminated with some dangerous bacteria, a thorough washing in boiling water is sufficient. But vessels in which milk is to be kept cannot be properly cleaned by pouring boiling water into one, allowing it to remain there for a few minutes, and then pouring it into another, and making one heating of the water suffice for the cleaning of several vessels. The last ones thus treated will not be much cleaner, so far as bacteria are concerned, than if they were washed with cold water. To clean vessels thoroughly, it is necessary to use a higher temperature than that of boiling water, which can be readily obtained by putting them for a few minutes in a hot oven or on a hot stove. If this is thoroughly done, there is no danger of contamination of milk from the milk vessels.

The use of sal-soda in washing milk vessels is advantageous, because it acts chemically upon fatty matters (grease), and thus helps to remove them and other materials which adhere to the vessels with them. In like manner, the use of "live steam" to "dry" vessels after washing, has the advantage of sterilizing them, *i. e.*, killing the bacteria by the highly heated steam.

SUMMARY.

1. Bacteria or microbes, as they are often called, abound in air, water, and soil, in animal and vegetable substances, and in living plants and animals. They are extremely minute and multiply with wonderful rapidity wherever the circumstances are favorable. Cold hinders their development. When heated long enough at the temperature of boiling water, they are killed, but their spores, which correspond to seeds, will endure even this temperature for some time, though higher heat kills them speedily.

2. Bacteria grow with the greatest readiness in milk and cream. Hence they collect in milk and cream exposed to the air, and multiply rapidly. In developing they cause the milk to sour and curdle and induce other changes in it. They also favor the ripening of cream.

3. Vessels in which milk and cream are to be kept are a great source of contamination by bacteria. The latter gather upon the sides and in the joints, and develop in the minute portions of milk, grease, or other matters from which it is difficult to free the walls of the vessels completely by washing.

4. A large number of different species of bacteria are found in milk and cream. Different species have different effects. Most of them sour and curdle milk at some temperature. A few induce changes that render milk alkaline without the formation of curd. When a curd is formed, it differs in character with different species of bacteria. The souring of milk is more complex than has been supposed; and while without much doubt souring always depends upon the action of bacteria, any one of a number of species, or several combined, may be the cause.

5. The longer a specimen of milk has been exposed to the action of bacteria, other things being equal, the greater will be the number of bacteria present. Hence it follows that cream will usually contain a very large number. The presence of these organisms, so far from being injurious, is of a positive advantage to the butter-maker, since it is by their action that cream is "ripened."

6. The ripening of cream appears to be even more complex than the souring of milk. While the ripening of cream is undoubtedly dependent upon the presence of bacteria, it is doubtful whether one species can produce what is known as ripened cream. Dairymen let their cream ripen before churning because their experience implies that the butter separates ("comes") more readily, keeps better, and is of better flavor.

A plausible explanation is that the bacteria break up the albuminous matter which encloses the particles of butter fat, so that the butter is more readily separated from it, and when made contains less of it. Since this albuminous matter affords support for bacteria, which cause butter to become rancid, it is natural to suppose that butter will keep the better the less it contains.

7. Two important points in the handling of milk and cream are brought out by these considerations:

First. The importance of keeping milk, so far as possible, free from bacteria and at a low temperature, in order that the cream may all separate before the milk sours.

Second. The advantage of keeping cream under circumstances favorable to the growth of the bacteria that induce ripening.

8. In brief, vessels in which milk is to be kept for creaming or for transport should be most carefully cleansed before the milk is put in them. As cold retards and heat, up to certain limits, favors the growth of bacteria, the advantage of keeping milk cold and cream warm is easily explained.

PUBLICATIONS OF THE STATION.

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STORRS SCHOOL AGRICULTURAL EXPERIMENT STATION,
STORRS, CONN.

CHAS. D. WOODS, CHEMIST.*

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*In the absence of the Director of the Station, Prof. W. O. ATWATER, who is engaged in the duties of Director of the Office of Experiment Stations of the Department of Agriculture in Washington, the Chemist of the Station serves as Acting Director.

PELTON & KING, Printers,
Middletown.

STORRS SCHOOL
Agricultural Experiment Station,
MANSFIELD, CONN.

(P. O. STORRS, TOLLAND CO., CONN.)

BULLETIN No. 5. OCTOBER, 1889.

ATMOSPHERIC NITROGEN AS PLANT FOOD.*

[This is a continuation of an investigation begun some years ago at Wesleyan University, Middletown, where the chemical work of the Station has been carried on since the establishment of the latter in 1888. The details of the experiments here reported, as of the previous ones, were conducted by Mr. C. D. Woods, formerly Assistant in Chemistry in Wesleyan University and now Chemist of the Station.]

Farmers in all older portions of the country buy large quantities of nitrogen in artificial fertilizers. Nitrate of soda, sulphate of ammonia, dried blood, cotton-seed meal and fish scraps owe their fertilizing value mainly, and Peruvian guano and tankage largely, to nitrogen, and the same element is one of the chief ingredients of bone manures, ammoniated phosphates and many other fertilizers. According to an estimate by the Connecticut Experiment Station, not less than $500,000 are expended annually for commercial fertilizers in Connecticut. A large amount of this goes for nitrogen, which is one of the dearest of the ingredients of fertilizers and costs at retail from eight or ten to eighteen cents or more a pound.

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* As the object of this BULLETIN is to briefly present facts of practical interest for farmers' reading, the details of these experiments are reserved for publication in the next Annual Report of the Station.

NITROGEN IN CROPS AND SOILS.

The quantities of nitrogen in ordinary crops and the cost of the same amount in the better commercial fertilizers are illustrated in the following table:

TABLE I.

Amounts of Nitrogen in Ordinary Crops and Cost of Same Amounts in Commercial Fertilizers.

KIND OF CROP AND AMOUNT PER ACRE.	NITROGEN.	
	Pounds per Acre.	Cost at 15c. per lb.
Corn.		
Grain, 50 bushels—2,800 pounds,	47.3	
Straw, 3,000 pounds,	25.4	
Total,	72.7	$10 91
Rye.		
Grain, 20 bushels—1,120 pounds,	19.0	
Straw, 3,500 pounds,	19.4	
Total,	38.4	5 76
Oats.		
Grain, 40 bushels—1,280 pounds,	23.3	
Straw, 2,000 pounds,	12.2	
Total,	35.5	5 33
Potatoes.		
Tubers, 150 bushels—9,000 pounds,	31.5	4 73
Clover Hay.		
Two tons—4,000 pounds,	80.3	12 05
Timothy Hay.		
Two tons—4,000 pounds,	39.4	5 91

The plants must have this nitrogen or they cannot grow. They obtain part of it from the soil and the rest from the air. The nitrogen of the soil has either been accumulated in the past or is supplied in manures. A small quantity, in the form of ammonia and other compounds of nitrogen, is continually brought to the soil by rain or snow. Late research implies that soils acquire nitrogen from the air by the aid of microbes or electricity or probably both. The nitrogen in the soil is being continually leached away by drainage waters, and more or less of it escapes into the air. Soils which are not cultivated, and from which the produce is not removed, accumulate more nitrogen than they lose, so that many virgin soils have a large stock. By ordinary cultivation and cropping, the nitrogen is gradually exhausted, unless it is returned by manures or otherwise.

NITROGEN OF THE ATMOSPHERE.

Of the total weight of the air, four-fifths are nitrogen. This means that over every square inch of the earth's surface there are twelve pounds of nitrogen, and over every acre of land, nearly 38,000 tons. If there are plants which can be used to gather any considerable amount of nitrogen from the air without cost, the fact is of immense importance, and ought to be clearly understood and rightly applied in practice.

Nearly all of the nitrogen of the air is in the form of what is called free nitrogen, that is, not combined with any other chemical element. A minute proportion is combined with other elements, in the forms of ammonia, nitric acid, etc. It has been agreed on all hands that the combined nitrogen of the air may be used by the plants; but the quantity is so extremely small as to be of comparatively little consequence.

DO PLANTS OBTAIN NITROGEN FROM THE AIR?—THE PROBLEM STATED.

The main questions have been:—

First. Can plants make use of atmospheric nitrogen to any considerable extent?

Second. If they do, is it the free nitrogen of the air that they acquire?

From the practical standpoint, it makes very little difference in what form the plants get the nitrogen, provided they can get enough. But, scientifically, these two questions are very different, and the chief dispute has been as to whether plants can utilize the free nitrogen of the air. Interesting as this problem is to the farmer, it is none the less so to the chemist and vegetable physiologist, and has been the subject of active discussion and experiment for more than fifty years. There are certain kinds of plants, like clover, beans, and others belonging to the family of the legumes or papilionaceae, which generally get on very well without nitrogenous fertilizers in worn-out soils, and it would seem as though these plants, at any rate, must in some way be able to make use of the nitrogen of the air. But the classic experiments of Boussingault, in France, of Lawes and Gilbert, in England, and others, have been widely accepted as proving that plants cannot use the free nitrogen of the air, and that they get practically very little combined nitrogen from the air, so that they are dependent upon that previously stored in the soil or supplied in manures. Still many experimenters have not regarded the question as definitely settled.

EARLIER EUROPEAN EXPERIMENTS.

While the experiments of Boussingault, and Lawes and Gilbert differ in their details, they agree in this, that the plants were under conditions widely different from those in ordinary culture. The especial object was to find whether plants acquire free nitrogen, and the plants were for the most part grown under cover, to exclude combined nitrogen, and in artificial soil containing little or no nitrogen. The growth was generally stunted and abnormal.

Later experiments on more or less similar plans have brought similar results. Investigations by Ville, in France, however, implied that plants can acquire nitrogen from the air, but his conclusions were not generally accepted.

PREVIOUS EXPERIMENTS AT WESLEYAN UNIVERSITY.

Some years ago a series of experiments was conducted by the writer, in which the conditions were more like those in which plants commonly grow. The method used was that of sand culture. By proper management, feeding, and watering, plants may be grown as large, as healthy, and in every way as well developed, in pure sand as in the richest soil. For these experiments sea sand was used. To remove all traces of material containing nitrogen (except, of course, air), the sand was carefully sifted, then washed, and finally heated in iron pots in a furnace, so hot that the pots nearly melted. It was then put in glass jars, water was added, in which were dissolved salts containing the mineral elements of plant food, potash, lime, iron, sulphuric acid, phosphoric acid, etc., and in some cases nitrogen in the form of nitrate of potash or lime. The seeds were then sown and the plants grew. They were kept in the open air in a building erected for the purpose. The arrangement was such that the plants were exposed in the daytime in pleasant weather, but put under cover when it rained and at night. They had enough plant food to enable them to make more or less growth independently of the nitrogen of the air, but were free to get the nitrogen from the air in case they were able to do so. They grew well; many of them were as well or better developed than those in a rich garden soil near by.

The amount of nitrogen in the seeds and in the nutritive solutions was determined by analyses at the beginning of the experiments. The same was done with the nitrogen in the plants at the end of the experiments and with that left in the nutritive solutions. The quantities of nitrogen supplied to the plants at the beginning and contained in them at the end of the experiment were thus determined. The plants were found to contain more nitrogen than had been supplied by the nutritive solutions and the seeds. For this gain there was but one possible source, the atmosphere. The peas had in some way acquired nitrogen from the air, and in some cases the quantities of atmospheric nitrogen thus obtained were very large. The results of these experiments were published in 1881, 1883, 1884 and 1885.*

Since that time a number of investigators have obtained similar and even more striking results, and much light has been thrown upon the ways by which the plants are enabled to obtain the nitrogen from the air.

EXPERIMENTS OF PROF. HELLRIEGEL AND OTHERS.

Professor Hellriegel in Germany has found from a large number of experiments that pea, lupine and serradella plants obtain large quantities of nitrogen from the air, while oats, barley and buckwheat seem to be restricted to that supplied to them in the soil and obtained through the roots. He has furthermore brought out the very important fact that there is a connection between the nitrogen acquired and the tubercles which are found on the roots of leguminous plants. The root tubercles are the bulb-like enlargements from the size of a pin-head to that of a pea or larger, sometimes called "warts," which are found on the roots of beans, peas, clover, cow-peas and other leguminous plants. They are often thought by persons not botanists to be indications of disease. This suggests that minute organisms, termed microbes, which are in some way connected with these tubercles, may be the agents by which the plants obtain nitrogen from the air.

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*Accounts were given briefly at the meetings of the American Association for the Advancement of Science, in 1881 and 1883, and the British Association in 1883, and published in detail in the *American Chemical Journal*, VI. pp. 365–388, and VIII. pp. 398–420.

To test the influence of the microbes in the soil, Prof. Hellriegel prepared soil infusions by putting small quantities of soil in water, shaking the mixture thoroughly and letting it settle. The water was then assumed to contain the microbes. The infusions thus prepared were put into the sand in which the plants grew. In a very remarkable series of trials it was found that where leguminous plants were supplied with mineral but no nitrogenous food, and received these infusions, they grew well, had tubercles upon their roots and contained large quantities of nitrogen when mature. Those which received no infusions or infusions which had been sterilized, *i. e.*, in which the microbes had been killed, made very little growth, had few or no tubercles and showed no gain of nitrogen. In another experiment Prof. Hellriegel grew peas and buckwheat inside a large glass globe as Boussingault had done, except that soil infusions were added. In both Hellriegel's and Boussingault's experiments the plants had practically no nitrogen except that in the seed and the free nitrogen of the air. Boussingault's plants made very little growth and showed no gain of nitrogen. The same was true of Hellriegel's buckwheat, but his peas grew well and gained considerable nitrogen. In other words, where the microbes were present the peas evidently utilized the free nitrogen of the air.

Prof. Wolff in Germany has reported experiments with clover which imply acquisition of atmospheric nitrogen. Numerous other late experiments indicate that both plants and soil obtain nitrogen from the air.

THE EXPERIMENTS HERE REPORTED.

The experiments described in this BULLETIN may be divided into the following series:

1888,	Champion of England Peas, - - - -	25 trials.
1888–9,	Alfalfa, - - - - - - - -	5 "
1889,	East Hartford Early Peas, first series, - -	33 "
1889,	Champion of England Peas, - - - -	16 "
1889,	Oats, - - - - - - - -	10 "
	Total, five series including, - - - - -	89 trials.

Other series with other plants are begun, but are not yet ready to be reported upon.

The following questions were proposed for study:

(1.) May plants, grown under normal conditions, acquire any considerable amount of nitrogen, free or combined, from the surrounding atmosphere?

(2.) What effect has the addition of soil infusions upon the formation of root tubercles?

(3.) Is there a definite relation between the formation of root tubercles and the acquisition of atmospheric nitrogen?

PLAN OF THE EXPERIMENTS.

The method was essentially the same as in the previous experiments by the writer above described. The plants were grown in glass jars containing sand, purified by washing and igniting. Nutritive solutions, either free from or containing known quantities of combined nitrogen in the form of nitrate of potash or lime, were applied to the sand. The amounts of nitrogen supplied in nutritive solutions and seed were compared with the amounts found at the end of the experiments in residual solutions and plants. The difference between these two amounts must show the loss or gain in nitrogen. A loss must indicate decomposition of either the organic nitrogen of the seed or plants or the nitric acid of the nitrates fed, or both. A gain must represent the nitrogen acquired from the air in excess of any lost either from organic matter of seed or plant or from nitrate of the food.

The conditions of growth were varied by varying the amounts of nitrogen supplied in nutritive solutions. The minerals needed for the growth of the plants were added in amounts to make one part or less by weight of dissolved salts in one thousand parts of the solution. Some of the plants received no combined nitrogen except that in the seed; to others nitrates were added, but in such small quantities that the minerals were relatively in excess; to others enough nitrogen was added to make the mixture of plant food correspond more nearly to the composition of the plants.

SPECIMEN EXPERIMENTS.

The methods may be illustrated by a description of one or two typical experiments.

Experiment No. 135, with East Hartford Early Peas.—The pot used in this experiment held 3 kilograms (six and a half pounds) of sand. This was placed in the pot April 10th, and the same day four peas, weighing 0.998 gram (15 grains) were planted. When planted they were fed with mineral salts, without combined nitrogen, in such amount that the ratio of salts to water was about 1 to 5,000. They were again fed with minerals on May 10th. During the period of growth, water was given them 41 times, 6.6 liters (somewhat over 6 qts.) being used.

About the middle of June two of the plants were through growing. These were not more than one foot in height, and when harvested were found to have no root tubercles. The other two kept growing, though not equally well, till about July 9th, when they were harvested. At this time one of the plants was two and one half and the other a little over five feet in height. Both had root tubercles. The four plants had 9 pods and 15 peas. The weight of the partly dried fruit and vines was 7.97 grams (123 grains). The roots, freed as far as practicable from sand, weighed 1.27 grams (20 grains), making the total weight of the four plants 9.24 grams (142 grains). The plants altogether contained 237.1 milligrams (3.65 grains) of nitrogen. The seed, as shown by analysis of similar ones, contained 39.9 milligrams nitrogen. The balance sheet of the experiment is as follows:

Nitrogen fed in the seed, - - -	39.9 milligrams	(0.61 grains).
Nitrogen found in plants, - - -	237.1 milligrams	(3.65 grains).
Gain, - - - - - -	197.2 milligrams	(3.04 grains).

The gain of nitrogen during the growth was thus 197.2 milligrams (3.04 grains).

In a large number of experiments, the plants have had no root tubercles. In nearly every case of this sort there has been more or less loss, instead of gain, of nitrogen. The natural inference is, that in the experiment just described, all the gain of nitrogen was made by the larger plants which had the root tubercles, and that they thus actually acquired from the air not only 197.2 milligrams (3.04 grains) of nitrogen which is counted as gain, but enough more to offset more or less loss where there were no tubercles.

Experiment No. 165, with Champion of England Peas.—Six kilograms of sand were placed in the pot April 15th, and the same day 6 peas, weighing 2.3 grams (35 grains), were planted. The plants were fed with minerals and with nitrogen in the form of calcium and potassium nitrates, when the seeds were planted, and on May 15th, June 20th, and June 22d. On May 11th and 20th, 25 c. c. of an infusion of garden soil in which peas were growing were added. During the whole period of growth the plants were watered 46 times, 13.9 liters (about 13 quarts) water being used. The plants had finished their growth and were nearly ripe on July 9th, when they were harvested. The notes taken at the harvesting were as follows:

Six Plants Grown in Sand.

HEIGHT.	NO. OF PODS AND PEAS.	
	Pods.	Peas.
3 feet 8 inches, - - - - - - -	1	2
4 " 9 " - - - - - - -	3	5
5 " 10 " - - - - - - -	4	7
4 " 0 " - - - - - - -	2	6
5 " 9 " - - - - - - -	3	7
5 " 6 " - - - - - - -	2	7
Total, - - - - - - - -	15	34

The roots had a good many tubercles, which were pretty evenly distributed. The partly dried vines and fruit weighed 24.85 grams (383 grains), roots freed from sand as completely as practicable, 7.87 grams (121 grains), making the total weight of the six plants 32.72 grams (504 grains). This contained 694.5 milligrams (10.70 grains) nitrogen. The soil (sand) at the end of the experiment contained 23.5 milligrams (.36 grains) nitrogen as nitrate. The balance sheet is as follows:

Nitrogen fed in the seed, -	105.1 mgr.	
Nitrogen fed in solution, -	447.7 mgr.	
	——	552.8 mgr. (8.51 grains).
Nitrogen found in soil, -	23.5 mgr.	
Nitrogen found in plants, -	694.5 mgr.	
	——	718.0 mgr. (11.06 grains).
Gain in nitrogen, - - - -		165.2 mgr. (2.55 grains).

In Table II. (see Appendix) the principal statistics of one series of experiments are given. This series, Champion of England Peas, is selected as it contains a small number (16) of experiments, and perhaps illustrates more clearly than any other the chief characteristics of the work and results.

DISCUSSION OF RESULTS.

Nitrogen Acquired from the Air. Loss of Nitrogen.—The answer to the question, " May plants grown under normal conditions acquire any considerable amount of nitrogen from the atmosphere?" coincides with the earlier experiments at this place, and is plain and unmistakable. Peas of small, early variety (Early Hartford) planted in sand, with no nitrogenous food except that in the seed, grew to a height of over five feet. With nitrogen supplied in the solutions, they sometimes reached a height of over eight feet. Many of the peas and alfalfa plants (see Appendix, Table III.) accumulated large quantities of nitrogen from the air. In one case, a single plant thus obtained more than one-third of a gram (54.6 grains) of nitrogen.

In a number of experiments with peas, in which the roots had few or no tubercles, instead of gain, there was a decided loss of nitrogen. This gives added force to the suggestion made in a report of the earlier work here,* that if nitrogen escaped in some of the trials, it may have escaped to some extent in other cases also. If so, the results are all inaccurate as indications of the actual atmospheric nitrogen acquired, and the plants must have really obtained more than the figures imply.

It may be that the loss of nitrogen is greater with some classes of plants than in others. The apparent loss in the experiments with peas was about as large when they were not fed combined nitrogen other than that in the seed, as when they were fed considerable quantities of nitrates. In the experiment with oats (see Appendix, Table V.), the results were very different. Without the addition of nitrates there was no loss, but a slight gain. When nitrates were fed there was loss, and the larger the amount of nitrates added, the greater was the loss of nitrogen.

These experiments do not tell to what extent the loss observed with the oats and with the peas which had no root tubercles was from the seed and to what extent from the nitrates; whether, as seems most likely, it was due to the action of microbes; or what connection there may be between plants of different species and the loss of nitrogen. These and kindred questions must remain for future research to decide. But one can hardly help coupling this observation of the large loss of nitrogen in the oat experiments with the common observation of practical farmers that oats are an exhaustive crop. The power of leguminous plants to acquire nitrogen from the air evidently explains in part why they are such valuable "renovating crops."

Experiments by Berthelot and others imply that nitrogen is being continually gathered from the air by soils, and that microbes and, probably, electricity aid the process. A large amount of late research tends to show that nitrogen compounds in the soil are being constantly decomposed by the action of microbes, and that the nitrogen thus set free escapes into the air.

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*Am. Chem. Jour. VIII. p. 403.

RELATION BETWEEN SOIL INFUSIONS AND ROOT TUBERCLES.

In Hellriegel's experiments the development of the root tubercles on the plants seemed to be dependent upon the addition of soil infusions. In ours, although the sand and water were sterilized, root tubercles were often abundant where no soil infusions were added (see Appendix, Table VI.). This was especially the case where the plants had some nitrogenous food. Indeed, where the plants were reasonably well fed, so far as the root tubercles were concerned, it made no apparent difference whether they had soil infusions or not; nor was there much difference where the plants had no nitrogen in their food. The plants were grown near a garden in which the soil was rich and the microbes, which seem to be connected with the root tubercles, were probably abundant. The most natural explanation is that the organisms or their germs (spores) were floating in the air, found their way to the pots in which the plants were cultivated and grew there, and that the growth of the microbes was especially favored where the plants had nitrates, *i. e.*, had food enough to keep them vigorous until the tubercles were formed.

RELATION BETWEEN ROOT TUBERCLES AND GAIN OF NITROGEN.

These experiments, like those of Hellriegel, reveal a remarkable relation between root tubercles and the acquisition of nitrogen from the air by plants. Leguminous plants thus far experimented with have root tubercles and acquire atmospheric nitrogen. Other plants have been found to be without root tubercles, and to gain little or no nitrogen, while in some experiments, as in those with oats, above cited, there is a large loss. There is an evident connection between root tubercles and microbes, though the exact nature of the microbes and their connection with the tubercles remain to be explained.

While there is as yet no positive proof that the root tubercles or the microbes are the cause of the gain of nitrogen, the fact that there is a connection between the root tubercles and the amount of nitrogen acquired by the plants from the air is unmistakable (see Appendix, Tables III. and IV.) In every case without exception where there were no root tubercles there was loss of nitrogen; where there were "few" tubercles there was sometimes a slight loss of nitrogen, at other times a slight gain; with a "fair number" of tubercles there was a decided gain; where there was a "large number" of tubercles the gain of nitrogen was very large.

It may be that this relation holds in fields as well as in pot culture. The past season the Station grew a half acre of cow-peas, which yielded at the rate of about eight tons of green fodder per acre. In some ten different places in the field the roots were examined and found to be covered with tubercles of large size. At one end of the field where the yield was relatively light the roots had less tubercles than elsewhere, and in general where the growth was heaviest the tubercles seemed to be most abundant.

As to whether the nitrogen which the plants obtain is the free or the combined nitrogen of the air, these experiments do not bring absolute proof, but the quantities of nitrogen obtained are so very large as to leave little doubt that it is free nitrogen; and the experiments of Hellriegel above cited would seem to prove that the uncombined nitrogen can thus be used. This and the cognate question as to how the nitrogen is acquired, demand further study. Investigations in this line are being planned for here.

SUMMARY.

1. Peas, alfalfa, serradella, lupine, clover in all probability, and apparently leguminous plants in general, are able to acquire large quantities of nitrogen from the air during their period of growth.

2. There is scarcely room to doubt that the free nitrogen of the air is thus acquired by plants.

3. That there is a connection between root tubercles and this acquisition of nitrogen is clearly demonstrated. What this connection is, what are the relations of micro-organisms to the root tubercles and the acquisition of nitrogen, and in general how the nitrogen is obtained, are questions still to be solved.

4. The cereals with which experiments have been completed have not manifested this power of acquiring nitrogen, nor do they have such tubercles as are formed on the roots of legumes.

5. In the experiments here reported the addition of soil infusions did not seem necessary for the production of root tubercles. A plausible supposition is that the micro-organisms or their spores were floating in the air and were deposited in the pots in which the plants grew.

6. As a rule, the greater the abundance of root tubercles in these experiments, the larger and more vigorous were the plants and the greater was the gain of nitrogen from the air.

7. *In a number of these experiments, as in similar ones previously reported, there was a loss of nitrogen instead of gain. The loss occurred where there were no root tubercles; it was especially large with oat plants, and largest where they had the most nitrogen at their disposal in the form of nitrates. As the gain of nitrogen by the legumes helps explain why they act as "renovating crops," the loss in the case of the oats suggests a possible reason why they should appear to be an exhaustive crop.*

PRACTICAL INFERENCES.

The ability of legumes to gather nitrogen from the air helps to explain the usefulness of clover, alfalfa, peas, beans, vetches, and cow-peas as renovating crops, and enforces the importance of using these crops to restore fertility to exhausted soils. The judicious use of mineral fertilizers (containing phosphoric acid, potash and lime,) will enable the farmer to grow crops of legumes, which after being fed to his stock will, with proper care to collect and preserve all manure, both liquid and solid, enable him to return a "complete fertilizer" in the shape of barn-yard manure to his land. A further advantage of growing these crops is that the nitrogenous material, protein, which they contain in such great abundance, is especially valuable for fodder.

IN CONCLUSION.

This subject has a wider significance than what has been said above implies. The future welfare of our race, material, intellectual, and moral, depends upon the food supply, or, in other words, upon the product of the soil. This in turn reduces itself essentially to a question of phosphoric acid, potash, and nitrogen. Enough of the first two for indefinite time to come is assured in the deposits of phosphates and potash salts already discovered, but the probability of a sufficient supply of nitrogen has been questioned. This costliest of the fertilizing elements escapes from our soils into the air and into the sea, and is taken away by crops, and not completely returned. Artificial fertilizers promise to meet but a small fraction of the coming demand. If, as has been urged, the exhaustless stores of the atmosphere are not available to plants, the outlook is dark enough. But if the farmer may use his crops to gather it, without money and without price, we may dismiss our solicitude. With the assurance that plants obtain nitrogen from the air, the fear of starvation for the over-populated earth of the future may be ignored. That research is bringing the brighter answer to this problem, there seems to be most excellent ground to hope.

TABLE II.

CHAMPION OF ENGLAND PEAS.—1889.

CONDENSED STATISTICS.

No. of Experiment.	Kilos of Sand.	Weight of Seed.	Nitrogen Supplied.			Soil Infusions.	Water.	Duration of Growth.	Root Tubercles at Harvest.	Mature Plants.							Nitrogen at End of Experim't.			
			In Seed.	In Nutritive Soluti'ns.	Total.					Number.	Extremes of H'ght.	Number of Pods.	Number of Peas.	Weight.			In Plants.	In Nutritive Solution.	Total.	Gain (or Loss) of Nitrogen
														Vines and Fruit.	Roots (and Sand.)	Total,				
		mgr.	mgr.	mgr.	mgr.	c. c.	c. c.	Days			Inches			gr.	gr.	gr.	mgr.	mgr.	mgr.	mgr.
151	3	1581	72.3	—	72.3	—	4200	78	None.	4	25–34	3	2	3.37	1.68	5.05	62.4	—	62.4	−9.9
152	3	1554	70.9	—	70.9	—	4300	78	None.	2	36–39	4	2	3.03	2.25	5.28	62.8	—	62.8	−8.1
153	3	1564	71.5	—	71.5	—	4400	79	Few.	4	32–40	3	3	2.69	1.26	3.95	58.0	—	58.0	−13.5
154	3	1553	71.0	—	71.0	50	4700	85	Fair Number.	4	36–46	6	8	5.72	2.45	8.17	145.8	—	145.8	74.8
155	3	1603	73.3	—	73.3	50	4800	85	Large Number.	4	44–50	5	8	5.99	2.74	8.73	151.9	—	151.9	78.7
156	3	1646	75.2	—	75.2	50	4700	85	Fair Number.	4	32–48	5	8	5.42	1.72	7.14	139.1	—	139.1	63.9
157	3	1543	70.7	151.8	222.5	—	7500	83	Fair Number.	4	44–51	8	14	12.47	7.96	20.43	282.7	—	282.7	60.2
158	3	1536	70.2	151.8	222.0	—	7600	85	Large Number.	4	54–62	10	16	14.52	3.84	18.36	343.8	3.8	347.6	125.6
159	3	1541	70.7	151.8	222.6	—	7800	85	Large Number.	4	48–64	9	18	14.38	4.67	19.05	340.0	2.0	342.0	119.4
160(1)	3	1552	70.9	151.8	222.7	50	8000	85	Large Number.	4	42–60	9	22	14.95	4.00	18.95	411.4	—	411.4	188.7
161	3	1588	72.6	151.8	224.3	50	7900	85	Few.	4	42–54	8	15	10.95	2.08	13.03	236.8	2.0	238.8	14.5
162	3	1643	75.0	151.8	226.8	50	8000	85	Large Number.	4	42–62	8	16	12.62	3.52	16.14	284.9	—	284.9	58.1
163	6	2405	109.9	447.7	557.6	—	12500	85	Few.	6	48–68	16	31	25.52	9.56	35.08	593.6	2.4	596.0	38.4
164(2)	6	2241	102.4	447.7	550.1	—	13000	85	Large Number.	6	48–68	18	30	27.67	10.75	38.42	672.7	20.5	693.2	143.1
165(3)	6	2300	105.1	447.7	552.8	50	13900	85	Large Number.	6	44–70	15	34	24.85	7.87	32.72	694.5	23.5	718.0	165.2
166(4)	6	2286	104.5	371.8	476.3	50	8900	54	Large Number.	6	42–64	—	—	17.27	6.67	23.94	618.2	105.5	723.7	247.4

(1) 8 peas eaten by birds. (2) 1 pea eaten by birds. (3) 3 peas eaten by birds. (4) Growth stopped when plant was in full bloom.

EXPLANATION OF TABLE.—In this series the plants in one group of six pots (No. 151–156) were grown without addition of nitrogen other than that in the seed; six pots (No. 157–162) with a small proportion; and four pots (No. 163–166) with a larger proportion. Half of the pots in each of these groups were treated with 50 c. c. of pea soil infusion. The number of tubercles was estimated at time of separating the roots from the sand, after harvest, but before analysis of plant. In the column "Extreme Height" the height of the shortest and the tallest plant in each pot is given. The weight of "Roots" and "Total" includes a small and varying amount of adhering sand, which it was not practicable to remove. When the peas were about half grown, some of the peas of the plants in Nos. 160, 164, and 165 were eaten by birds. No correction for the nitrogen thus lost is made, so the calculated gain given in the last column is less than the actual gain. Ants attacked No. 166 when the plants were in blossom. The attempt to drive them out with a small quantity of borax was successful, but the plants were killed thereby.

TABLE III.

EXPERIMENTS WITH PEAS AND ALFALFA,

1888-1889.

SUMMARY OF RESULTS.

	Root Tubercles.	No. of Experiments.	No. of Plants in Experiments.	Gain (or Loss) of Nitrogen.
Champion of England Peas, 1888.				
Not fed with nitrogen except that in seed, - - - - - -	None, - -	6	13	—9.8
	Few, - -	1	3	—1.7
	Fair number,	1	3	85.6
	Large number,	1	3	116.7
	Total, -	9	22	
Fed with 76 to 152 milligrams nitrogen as calcium and potassium nitrates in addition to that in seed, - - -	None, - -	6	13	—22.7
	Few, - -	4	11	— 3.1
	Fair number,	3	9	19.7
	Large number,	3	9	49.0
	Total, -	16	42	
East Hartford Early Peas, 1889. First Series.				
Not fed with nitrogen except that in seed, - - - - - -	None, - -	2	4	—9.6
	Few, - -	5	14	0.1
	Fair number,	1	4	28.7
	Large number,	8	23	72.9
	Total -	16	45	
Fed with 76 to 228 milligrams nitrogen as calcium and potassium nitrates in addition to that in seed, - - -	None, - -	—	—	—
	Few, - -	6	18	—5.6
	Fair number,	3	11	26.4
	Large number,	8	26	74.5
	Total -	17	55	
Champion of England Peas, 1889. First Series.				
Not fed with nitrogen except that in seed, - - - - - -	None, - -	2	6	—9.0
	Few, - -	1	4	—13.5
	Fair number,	2	8	69.4
	Large number,	1	4	78.7
	Total, -	6	22	

TABLE III.—*(CONTINUED.)*

	Root Tubercles.	No. of Experiments.	No. of Plants in Experiments.	Gain (or Loss) of Nitrogen.
Champion of England Peas, Etc. (Continued.)				
Fed with 152 to 448 milligrams nitrogen as calcium and potassium nitrates in addition to that in seed, - - -	None, - -	—	—	—
	Few, - -	2	10	26.5
	Fair number,	1	4	60.2
	Large number,	7	34	149.6
	Total, -	10	48	
Alfalfa.				
Not fed with nitrogen except that in seed, - - - - - -	None, - -	—	—	—
	Few, - -	—	—	—
	Fair number,	1	3	137.5
	Large number,	—	—	—
	Total, -	1	3	
Fed with 340 milligrams nitrogen as calcium and potassium nitrates, - -	None, - -	—	—	—
	Few, - -	3	4	84.0
	Fair number,	—	—	—
	Large number,	1	1	382.2
	Total, -	4	5	

In Table III. a summary of the results of the experiments with peas and alfalfa is given. The results are arranged in accordance with the number of root tubercles observed at the time of harvest. While it is not practicable to give more than a relative idea of their abundance, this grouping them into few, fair number, and large number, presented but little difficulty. The estimate of the number of tubercles was made before the analysis of the plants, and thus the observer was free from all bias. In each series, part of the plants were not fed combined nitrogen other than that in the seed, while a part received varying amounts of potassium and calcium nitrates.

TABLE IV.

EXPERIMENTS WITH PEAS AND ALFALFA, 1888–1889.

Condensed Summary of Results and Averages.

	Root Tubercles.	Without Nitrogen in Nutritive Solutions.			With Nitrogen in Nutritive Solutions.			Total.		
		No. of Experiments.	No. of Plants in Experiments.	Gain (or Loss) of Nitrogen.	No. of Experiments.	No. of Plants in Experiments.	Gain (or Loss) of Nitrogen.	No. of Experiments.	No. of Plants in Experiments.	Gain (or Loss) of Nitrogen.
Peas.	None, - - - -	10	23	—9.6	6	13	--22.7	16	36	—14.5
	Few, - - - -	7	21	—2.1	12	39	0.6	19	60	—0.4
	Fair number, -	4	15	63.3	7	24	28.4	11	39	41 1
	Large number, -	10	30	77.9	18	69	99.5	28	99	91.7
Alfalfa.	None, - - - -	—	—	—	—	—	—	—	—	—
	Few, - - - -	3	4	84.0	—	—	—	3	4	84.0
	Fair number, -	—	—	—	1	3	137.5	1	3	137.5
	Large number, -	1	1	382.2	—	—	—	1	1	382.2

In Table IV. a condensed summary of Table III. is given. In this table the Champion of England and East Hartford Early Peas are arranged together.

TABLE V.

EXPERIMENTS WITH OATS, 1889.

	No. of Experiments.	No. of Plants in Experiments.	Gain (or Loss) of Nitrogen.
Not fed nitrogen except in seed, - - - - -	4	24	2.3
Fed 304 milligrams nitrogen as calcium and potassium nitrates, - - - - - - -	3	18	—101.5
Fed 607 milligrams nitrogen as calcium and potassium nitrates, - - - - - - -	3	18	—207.8
Total, - - - - - - - - -	10	60	

Table V. epitomizes the results of the experiments with oats. The experiments are arranged in accordance with the amount of combined nitrogen fed. No tubercles were found upon the roots. It will be noticed that plants that were not fed with nitrates made a very slight gain, (the largest gain was 3.1 and the smallest 1.6 milligrams,) while in each case where nitrates were supplied there was a considerable loss and that the loss increased with the amount of nitrates added. Doubling the nitrogen fed doubled the loss of nitrogen.

TABLE VI.

RELATION BETWEEN SOIL INFUSION AND TUBERCLES.

Numbers of Experiments in which were no root tubercles, a few, a fair number, or a large number, as estimated at harvesting.

		Champion of England Peas, 1888.	Alfalfa	East Hartford Early Peas, 1st Series, 1889.	Champion of England Peas, 1889.	Total Number of Experiments.	Per Cent. of Total No. of Experiments.
WITHOUT SOIL INFUSION,	No tubercles, -	2	—	1	2	5	15.6
	Few tubercles, -	2	2	2	2	8	25.0
	Fair number, -	1	—	2	1	4	12.5
	Large number, -	1	—	11	3	15	46.9
	No. of Exp'mnts,	6	2	16	8	32	100.0
WITH SOIL INFUSION, -	No tubercles, -	0	—	1	0	1	2.7
	Few tubercles, -	2	1	9	1	13	35.1
	Fair number, -	2	1	2	2	7	18.9
	Large number, -	4	1	6	5	16	43.3
	No. of Exp'mnts,	8	3	18	8	37	100.0

Table VI. recapitulates the results of 69 experiments, 64 with peas and 5 with alfalfa. The first group contains 32 experiments with peas and alfalfa, to which no soil infusions were added. The last column shows the percentage of experiments in which there were tubercles at harvest. It will be seen that the plants in 47 per cent of the experiments had a "large number" of tubercles, notwithstanding they received no soil infusion. The second group contains 37 experiments with alfalfa and peas, all of which were treated with soil infusion. In only 43 per cent. of them were there a "large number" of tubercles.

METEOROLOGICAL OBSERVATIONS.

Observations of temperature, pressure, and state of the weather are made at the Station three times each day, viz.: at 7 A. M. and 2 and 9 P. M.

SUMMARY, JULY 1 TO SEPT. 30, 1889.

Observations made at Mansfield by E. A. Bailey.

	JULY.	AUG.	SEPT.
Highest Barometer,	30.27	30.30	30.32
Lowest Barometer,	29.69	29.81	29.51
Mean Barometer,	29.98	30.08	30.05
Highest Temperature,	85.8	81.0	80.8
Lowest Temperature,	49.3	46.2	36.0
Mean Temperature,	67.9	64.9	59.7
Relative Humidity,	84.4	82.5	85.1
Total Precipitation,	11.39	3.78	4.00
No. of days with precipitation of .01 inches or more,	13	9	14
No. of clear observations,	45	56	34
No. of cloudy observations,	41	37	51

In accordance with the wish of the Station, copies of the publications will be mailed to all citizens of Connecticut and to Granges, Farmers' Clubs, and other agricultural organizations, who ask for them, and so far as circumstances permit, to those who apply from other States. Requests for publications and business communications should be addressed to

STORRS SCHOOL AGRICULTURAL EXPERIMENT STATION,
STORRS, CONN.

W. O. ATWATER, *Director.*

PELTON & KING, PRINTERS,
MIDDLETOWN.

STORRS SCHOOL

Agricultural Experiment Station,

STORRS, CONN.

BULLETIN No. 6.—AUGUST, 1890.

GRASS AND FORAGE GARDEN.

GRASSES AND LEGUMES.

PUBLICATIONS OF THE STATION.

The publications of the Station will be mailed to all citizens of Connecticut and to Granges, Farmers' Clubs, and other agricultural organizations, who ask for them, and so far as circumstances permit, to those who apply from other States. Requests for publications and business communications should be addressed to

STORRS SCHOOL AGRICULTURAL
EXPERIMENT STATION,
STORRS, CONN.
Tolland County.

ONE of the first lines of work undertaken by the Station was a study of the growth of various forage plants, with the hope of learning something of their adaptability to the soils and climate of the State and their value for feeding and manure. The extent and rapid development of the dairy interest in Connecticut make it important for the farmer to understand the relative values of our common grasses and other fodders, as well as the merits of the newer varieties. A knowledge of the green fodders and hays is necessary to a rational use of the more concentrated feeding stuffs, such as bran, gluten meal, linseed and cotton-seed meals, and corn meal. Corn stover or coarse meadow hay requires to be combined with grain in quite different proportions from clover, vetch, or cow peas, in order to make a well balanced ration for feeding.

One way of studying the peculiarities of forage plants is by cultivating various kinds side by side and observing the differences in growth. Combined with chemical analysis, this goes far toward showing their relative values for feeding and for making manures.

PURPOSE OF THIS BULLETIN.

The purpose of this BULLETIN is to call attention to (1) some of the plants grown in the Grass and Forage Garden of the Station, (2) the outcome of trials on the growth of plants for hay and green fodder, and (3) especially the high feeding and manurial values of some leguminous plants which are or can be grown in Connecticut.

The new results here reported consist mainly of observations on the growth of eight species of legumes: horse bean, *Vicia faba;* soja bean, *Soja hispida;* cow pea, *Dolichos sinensis;* vetch, *Vicia sativa;* white lupine, *Lupinus alba;* blue lupine, *Lupinus hirsutus;* yellow lupine, *Lupinus luteus;* and clover, *Trifolium pratense;* and one grass, tall meadow fescue, *Festuca elatior*, with analyses of the products, including roots and stubble.

A study of the effects of nitrogenous fertilizers upon the quantity and composition of the grass crop, similar to that begun upon corn, already reported,* was commenced the present season.

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*Annual Reports of this Station, 1888, page 72, and 1889, pages 103 and 127.

These experiments have, for the most part, been conducted in the Forage Garden and upon the School farm, though a few have been on farms in different parts of the State. It is planned to continue this work, the present BULLETIN being regarded merely as a report of progress.

As the purpose of the present BULLETIN is to give brief statements of results for use of farmers, the details are reserved for publication in the next Annual Report of the Station.

THE GRASS AND FORAGE GARDEN.

The land is low and level and generally free from stones. The soil varies from a medium heavy loam to a clay loam, with a compact clayey sub-soil, which retains water and is but little affected by drought. The whole area is about one-half acre. One portion is laid out into sections about 140 feet long and eight feet wide, with paths four feet in width between the sections. The plants are grown in drills crosswise of the sections, from two to five or more drills being devoted to each species. The plants are thus grown, in order to afford as complete control as possible of varieties and to facilitate keeping weeds in subjection. Each species is labeled with a card showing the scientific and common name.

Another portion is laid out into plats of one to five square rods each, for use in growing legumes, and a third portion into one-twentieth acre plats for testing some of the more promising varieties of grasses on a larger scale.

LIST OF PLANTS GROWN IN THE FORAGE GARDEN DURING 1889–90.

Agrostis perennans,	Wood red-top.
Agrostis scabra,	Hair-grass. Thin-grass.
Agrostis stolonifera,	Creeping bent-grass.
Agrostis vulgaris major,	Tall red-top.
Agrostis vulgaris minor,	Small red-top.
Aira caespitosa,	
Aira flexuosa,	Hair-grass.
Alopecurus pratensis,	Meadow fox-tail.
Alopecurus agrestis,	
Andropogon furcatus,	Blue-stemmed brome grass.
Anthoxanthum odoratum,	Sweet vernal grass.
Anthryllis vulnerarea (?),	Kidney vetch (?).
Apera spica venti,	Awned bent-grass.
Avena (arrhenatherum) elatior,	Tall meadow oat-grass.

Avena flavescens flexuosa,	Yellow oat-grass.
Bromus inermis,	
Bromus mollis,	Soft chess.
Bromus schraderi,	Schrader's grass.
Bromus secalinus,	Cheat. Chess.
Bromus tectorum,	Brome grass.
Cynosurus cristatus,	Crested dog-grass.
Dactylis glomerata,	Orchard grass.
Danthonia spicata,	Wild oat-grass.
Dolichos sinensis, L.,	Cow pea.
Elymus Virginicus,	Wild rye-grass.
Eragrostis pectinaceæ,	Eragrostis.
Festuca duriuscula,	Hard stemmed fescue-grass.
Festuca fluitans,	Water-fescue.
Festuca heterophylla,	Various leaved fescue-grass.
Festuca ovina,	Sheep's fescue.
Festuca elatior,	Tall meadow fescue.
Festuca elatior, pratensis,	Smaller meadow fescue.
Festuca rubra,	Red fescue-grass.
*"*Fescue No. 1*,"	
Glycera fluitans,	Floating manna-grass.
Hedysarum coronarium,	
Hedysarum onobrychis,	Sainfoin.
Holcus lanatus,	Velvet grass.
Indigofera tinctoria,	Indigo.
Lathyrus hirsutus,	
Lespedeza striata,	Japan clover.
Lolium Italicum,	Italian rye-grass.
Lolium perenne,	Perennial rye-grass.
Lotus corniculatus,	Bird's-foot clover.
Lotus villosus,	
Lupinus hirsutus,	Blue lupine.
Lupinus alba,	White lupine.
Lupinus luteus,	Yellow lupine.
Medicago lupulina,	Black-seeded medick.
Medicago alba,	White sweet clover.
Medicago cœrulius,	Blue sweet clover. Bee clover.
Ornithopus sativa,	Serradella.
Panicum anceps,	Two-edged panic-grass.
Panicum (Setaria) Italica,	Hungarian grass.
Panicum virgatum,	Tall panic-grass.
Phalaris arundinaceæ,	Reed canary-grass.
Phleum pratense,	Timothy. Herd's grass.
Poa annua,	Low spear-grass.
Poa arachnifera,	Texas blue grass.
Poa compressa,	Wire grass. English blue grass.

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* From J. B. Alcott, South Manchester, Conn., and Department of Agriculture. Species undetermined.

Poa serotina,	Fowl meadow-grass.
Poa trivialis,	Rough-stalked meadow-grass.
Trifolium hybridum,	Alsike clover.
Trifolium incarnatum,	Scarlet or French clover.
Trifolium pratense,	Common red clover.
Trifolium repens,	White clover.
Sorghum halpense,	Johnson grass.
Soja hispida,	Soja bean.
Spergula maxima,	
Vicia faba,	Horse bean.
Vicia sativa,	Spring vetch. Tare.

A FEW PROMISING GRASSES.

Attention is here called to some grasses which seem worthy of a more general trial in this State. Timothy and red top are, and will very likely remain, our standard grasses; but species which will mature at other times, so as to make it surer to cut all of the hay at the best period of growth, and which will also be well adapted to special localities and conditions, are wanted to supplement timothy and red top.

Orchard Grass *(Dactylis glomerata)* is a widely diffused grass, peculiarly adapted to many conditions of soil, climate, and treatment. It is large, ordinarily three and one-half to four feet tall at time of bloom, which is about June 5 to 10. The stems are heavy and coarse and become woody if allowed to stand long after flowering. Two crops a year are commonly obtained. The chief objection to the grass is its tendency to grow in tussocks, leaving the ground only partially covered and producing a rough sward. This may be overcome by heavy seeding, or by growing with other grasses maturing at about the same time.

Tall Meadow Oat Grass *(Avena elatior)* blossoms about the same time as orchard grass, and could perhaps be seeded with it to advantage. It has been grown but little in New England, but appears to be a grass of a good deal of promise. It is a rapid grower, reaching a height of three and one-half to four feet at time of flowering. A vigorous second growth starts up as soon as a crop is removed. It thrives well on rather dry soils where many grasses would not succeed. Three quite heavy cuttings were made from the drills in the garden of the Station in 1889.

An effort was made to grow this grass on a larger scale the present season, but the seed obtained proved very impure, consisting largely of chess, with a slight mixture of oat grass. Seed houses might do well to secure the pure seed and endeavor to introduce the grass.

TALL MEADOW FESCUE *(Festuca elatior)* is the unusually dark green species sometimes known as "evergreen grass." It blossoms ~~July~~ [illegible] 15th to 20th, and produces a heavy growth, three to three and one-half feet tall. It is leafy and succulent, and has proven a valuable grass for moist meadows.

A plot of 220 square feet, sown broadcast in August, 1889, was cut June 24, 1890, when a little past bloom. The yield was at the rate of nearly ten tons of green crop per acre, equal to about three tons of hay, containing two and one-half tons of dry matter. An analysis is given in Table 1, page 12.

FOWL MEADOW GRASS *(Poa serotina)* somewhat resembles common blue grass *(Poa pratensis)*. It remains fresh and green longer and does not blossom until some three weeks later than blue grass. It comes into bloom about the first week in July. It is a grass of medium fineness, two to two and one-half feet tall, leafy and succulent. A peculiarity is that it remains fresh and green long after flowering. It is well adapted to moist meadows and might be grown with timothy to advantage. As with meadow oat grass, we have experienced difficulty in procuring pure seed.

PERENNIAL RYE GRASS *(Lolium perenne)* is said to occupy "the same place in Great Britain that timothy does with us, and is there esteemed, on the whole, higher than any other species of grass." It produces a medium heavy growth, two to two and one-half feet tall. It is leafy and succulent, and makes a thick "bottom growth." It blossoms June 20 to 25. Its tendency to produce a thick undergrowth gives it value for growing with taller and more slender species.

LEGUMES.

The legumes, of which clover is a leading representative, are very important fodder plants, when grown either as forage crops or for hay. They belong to the botanical order of the leguminosae or pulse family, and differ greatly from the grasses in their botanical and economical characteristics.

Among the reasons why legumes are especially valuable for feeding and manures, are:

1. They contain large proportions of protein (nitrogen compounds).

Hay from our ordinary grasses contains from 5 to 9 per cent. of protein, corn fodder a little less, and corn stalks and straw from 3.5 to 8 per cent., while hay from clover, cow peas, alfalfa, etc., cut in blossom or before, contains from 12 to 17 per cent., and the seeds a much larger proportion.

2. In general, plants of this class respond readily to the application of mineral fertilizers, such as phosphates, potash salts, and very commonly to plaster and lime. Nitrogenous fertilizers, nitrate of soda, sulphate of ammonia, dried blood, etc., which are more costly, have generally less effect upon the legumes. The reason seems to be that they are, as a class, able to obtain nitrogen for themselves both from the air and from the soil.

Their faculty of obtaining nitrogen from the air seems to be connected with nodules upon their roots, the so-called root tubercles, which seem to be dependent upon the action of bacteria or other minute organisms.*

The power of legumes of obtaining nitrogen from the soil seems to depend, at least in part, upon their root development. The large number of roots of many of this class of plants, and the depths to which they penetrate, make it possible for them to obtain food which is beyond the reach of other plants. It may also be due in part to their ability to utilize nitrogen compounds which are not available to certain other plants, *e. g.*, wheat, oats, grasses, etc.

3. One of the most important peculiarities of this family of plants is their ability to acquire atmospheric nitrogen. Experiments in this laboratory in the years 1881–2, proved that peas had this power. Since then these experiments have been repeated in this and in European laboratories, and our earlier results have been amply confirmed and added to.

Many kinds of plants have been experimented with, but none outside of the legumes have shown any special power to utilize the free nitrogen of the air. While it is likely that many, if not all, of the legumes have this power, it has been shown that peas, alfalfa, serradella, lupine, and vetch are able to acquire large quantities of nitrogen from the air during their period of growth.

4. The manurial value of this class of plants depends upon the large amount of plant food in both the tops and the roots. When the crop is fed, four-fifths or more of the nitrogen, and a

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* See Bulletin No. 5 of this Station, and Annual Report for 1889, page 11.

still larger proportion of the phosphoric acid, potash, and other mineral fertilizing ingredients go into the excrement, liquid and solid; if these are preserved they make very rich manure. If the crop is plowed under, its plant food, including that acquired from the air and that gathered from the sub-soil, is left for the use of succeeding crops. When the crop is removed the roots and stubble still remain with their large amounts of fertilizing material.

PRINCIPAL LEGUMES GROWN AT THE STATION.

Clover.—Our common clovers are too well known to need description. The red clover *(Trifolium pratense)* is the one chiefly grown for fodder. Mammoth red clover (a variety of *Trifolium pratense*) was sown in the Forage Garden, April 15th, 1889. It made a fair growth during the summer, and reached full bloom about August 10th. The yield of green clover was at the rate of 12.3 tons per acre, containing 76 per cent. of water and 24 per cent. of dry substance. The yield of dry substance was about three tons per acre, which would make about three and one-half tons of hay.

Vetch *(Vicia sativa)* is a low-growing, twining plant, resembling a small pea. The stem is light and the plant, as a whole, is soft and succulent, and on this account is advantageously grown with oats and barley. In an experiment at the Station, a mixture of one bushel of oats with two bushels of vetch per acre was used as seed. This brought oats enough to support the vetch when cut before the oats began to ripen. Scotch vetch was used, a variety which seems to be larger and more productive than the common English vetch. The mixture was sown April 20th. Cutting for fodder began July 3d, at which time the vetch was in full bloom. The vetch continued green and succulent until the oats were ripe. July 1st, when the oats were a little past bloom, six average square rods gave a yield at the rate of 8.6 tons per acre. The mixture furnished a fodder richer in protein than oats alone. It was freely eaten by milch cows.

When the vetch was in bloom and the oats a little past bloom, a sample was taken for analysis. The results of this analysis, the average of two samples of vetch analyzed in 1888, and the average of the analyses of two samples of oat fodder compiled by the Connecticut State Station follow:

	OATS AND VETCH.	VETCH.	OATS.
Water,	80.3	79.2	74.9
Water-free (dry matter),	19.7	20.8	25.1
In water-free:			
Protein,	12.6	19.7	7.0
Fat,	4.8	2.1	2.4
Nitrogen-free extract,	41.6	32.1	50.6
Fiber,	33.5	30.2	32.9
Ash,	7.5	15.9	7.1

SERRADELLA *(Ornithopus sativus)* is a low-growing, succulent fodder plant, resembling vetch. It makes a somewhat slow growth, and we have found it desirable to sow in drills in order to control the weeds. Its value has not been sufficiently tested in this State, but at the Massachusetts State Station it has been grown with much success, from ten to thirteen tons of green crop having been obtained per acre. In 1888 the Station plots were attacked with mildew and produced no fodder of value.

COW PEA *(Dolichos sinensis)*.—In general appearance this plant resembles a large bush bean more than a pea. At the South it is grown extensively, both for seed and forage. It thrives on much poorer soil than clover, and is frequently plowed under for restoring light, worn-out soils. In our climate it needs a warm soil and thorough cultivation for the best results. It is of value both for green feed and for ensilage. For the past two seasons the Station has grown from one-half to one acre, and obtained a yield of about eight tons of green fodder per acre, which would be equivalent to about two tons of cured cow pea hay, and would contain one and one-half tons of dry matter. Both crops were made into ensilage, which came from the silo well preserved, and was as freely eaten by stock as the best corn ensilage. Since the fodder is entirely new to most of our animals, they are quite apt to refuse it at first. If placed in the mangers at night, they generally begin to test it before morning, and in a few days eat it freely.

According to our experience, the peas should be sown in drills two and one-half to three feet apart, from May 20 to 30. They usually make slow growth at first, and need frequent cultivation to keep the weeds subdued. They are ready for feeding from August 20 to 30, and if used for silage should be placed in the silo before danger of frost.

LUPINES.—Three species are commonly grown,—the white *(Lupinus alba)*, the blue *(Lupinus hirsutus)*, and the yellow *(Lupinus luteus)*.

The plants are bushy, somewhat woody, and generally too coarse for good fodder, though they are used in some countries for sheep feed. They contain a bitter compound not relished by stock, but may have a valuable place in green manuring, as they are rapid growers and produce large amounts of organic matter, and, like other legumes, gather large quantities of plant food from soil and air, which are useful for succeeding crops. Their value in this direction is worthy of careful test.

ALFALFA *(Medicago sativa)*.—This valuable forage plant has not been experimented with at the Station, but has been successfully grown by the Experiment Stations and by farmers in New Jersey and in New York. In Vermont it was tried under the auspices of the Experiment Station upon thirty farms in different parts of the State, and although it did well the first summer, most of it was winter-killed in the following winter. It has, when successfully grown, most of the good qualities of a forage plant, with few poor ones.

If farmers wish to try this crop, it would be well to begin with a small piece of well prepared land, as it is probable that success with alfalfa depends largely upon having a good, carefully prepared seed-bed and fresh seed, lightly covered by rolling. A light mulching has been recommended for protection during the first winter.

PROXIMATE COMPOSITION OF SOME LEGUMES.

[Analyses of feeding stuffs usually include the estimation of water, protein, fats, nitrogen-free extract (carbohydrates other than fiber), fiber and ash.

Water is present in all feeding stuffs in amounts varying from five to fifteen per cent. in dry hays, and reaching eighty or ninety per cent. in green fodders.

Protein includes the nitrogenous compounds, the more important of which are the albuminoids, or albumen-like substances which we are familiar with in whites of eggs, casein (curds) of milk, lean of meat, gluten of wheat, etc. Besides the albuminoids in vegetable substances, there are other nitrogen compounds known as amides, etc., which are less valuable for feeding purposes than the albuminoids.

The "fat" or "ether extract" includes a wide class of compounds extracted by ether. In addition to the fats or oils proper, it may contain lecithins, wax, resins, chlorophyl (the green coloring matter of plants), etc.

Nitrogen-free extract is found by difference, *i. e.*, by subtracting the sum of the percentages of the other ingredients from 100 per cent. It consists of starch, sugar, gums, and other substances not so well known.

Fiber is the woody part of a plant, consisting mainly of cellulose. Cotton is nearly pure cellulose.

All parts of plants contain more or less mineral matters or ash, and generally in more than sufficient amounts for feeding purposes.

The protein (nitrogenous portion) of a feeding stuff is indispensable to the formation of blood, muscle, and sinew, and to the production of milk, and hence their compounds are often called "flesh formers," while the fats and carbohydrates (the non-nitrogenous portion) are called "fat formers," since in the animal economy they are usually changed into fat or used as fuel to maintain animal heat and give muscular power and strength for work.

Not all of the food eaten by an animal is digested and assimilated. Many experiments have been conducted in Europe, and a few in this country, to determine how much of a given feeding stuff is digestible. The results of European digestion experiments are not entirely applicable to our feeding stuffs. Since data regarding the composition and digestibility of American feeding stuffs are being compiled, and will, it is expected, soon be published by the Office of Experiment Stations of the Department of Agriculture, it has not been thought best to make calculations for this BULLETIN of the quantities of digestible nutrients in the samples of which analyses are here reported.]

In Table 1, which follows, are given the proximate analyses of the principal legumes and one species of grass grown by the Station. The average of the results of 81 analyses of corn and corn stover, also made by the Station, and of 55 American analyses of timothy hay and 10 of timothy and red top hay, as compiled by Dr. Jenkins of the Connecticut Station, are given for comparison.

The first column shows the number of analyses upon which the figures are based. The percentages of water and water-free substances are calculated at the time of harvest;—the legumes, on moisture content of green crop at time of cutting; and corn, at time of husking, which was some weeks after cutting, *i. e.*, field cured. The low percentage of water in the sample of soja bean is due to its maturity at time of cutting. It will be noted that the clover, vetches, and cow peas had about 80 per cent. of water and the lupines more than 85 per cent.

The percentages of protein, fat, etc., are calculated on the dry or water-free substance. As given in the table, the figures show the percentage composition. They may also be considered as the *number of pounds* of each ingredient in 100 pounds of dry matter (water-free substance). The last column gives the number of pounds of the crop at time of harvest (with water content given in the second column) that would be necessary to furnish 100 pounds of dry matter.

The large proportion of protein in legumes is clearly shown in the table, being from two to three times that of timothy hay.

The close approximation of the average of New England grown corn and stover to timothy hay enforces the importance of this material for feeding purposes. It is probable that the figures given for the composition of corn and stover are very near the average composition of the dry matter of New England grown flint corn, but many more analyses will have to be made of the legumes before the results can be accepted with the same confidence.

TABLE 1.

COMPOSITION OF SOME LEGUMES AS COMPARED WITH CORN AND HAYS.

Percentages of water and dry (water-free) substance in green or field-cured crops; ingredients in 100 parts of water-free substance (actual nutritive materials); weights of crop as harvested which would be required to furnish 100 pounds of water-free substance.

	Number of Analyses.	AT HARVEST.		IN WATER-FREE SUBSTANCE.					Pounds of green crop as harvested required for 100 lbs. dry matter.
		Water.	Water-free Substance (Dry Matter).	Protein.	Fat.	Nitrogen-free Extract. (Carbohydrates, etc.)	Fiber.	Ash.	
		%	%	%	%	%	%	%	Lbs.
Horse bean, past bloom,	1	83.5	16.5	18.5	3.1	35.7	33.2	9.5	606
Soja bean, seeds nearly grown, - -	1	73.8	26.2	20.7	8.5	40.8	19.8	10.2	382
Cow pea, vines, - -	2	81.1	18.9	14.0	2.5	48.5	22.7	12.3	529
Vetch, in bloom, - -	2	79.8	20.2	19.7	2.1	32.1	30.2	15.9	495
White lupine, nearly past bloom, -	2	85.4	14.6	15.6	2.4	36.0	34.9	11.1	685
Yellow lupine, past full bloom, - -	2	89.1	10.9	16.7	2.3	39.4	31.5	10.1	917
Blue lupine, nearly past bloom, - -	2	86.7	13.3	14.9	2.2	39.3	31.6	12.0	752
Red clover, in full bloom,	4	81.5	18.5	17.5	2.9	39.9	29.5	10.2	539
Flint corn, grain, field cured, - -	81	27.1	72.9	11.4	5.7	79.4	1.7	1.8	137
Flint corn, stover, field cured, - -	81	48.1	51.9	6.8	1.9	51.4	33.6	6.3	153
Tall meadow fescue grass,	2	75.3	24.7	8.4	3.3	44.8	36.4	7.1	405
Timothy hay,* - -	55	10.2	89.8	6.8	2.4	52.3	33.8	4.7	‡333
Timothy and red top hay,*	10	12.4	87.6	7.4	2.3	50.5	34.3	5.5	‡333

* Average of American analyses compiled in Conn. Ag. Exp. Station Report for 1888.

‡ Assuming 70 per cent. of water in the green crop as mown.

In the following table, No. 2, the tons of green crop and pounds of protein, fat, nitrogen-free extract, and fiber per acre are given as computed from the analyses given in Table 1. The yield of green crop per acre, in the case of the legumes, was obtained from plots grown in the Forage Garden, and are on this account somewhat unreliable as compared with the yields that might be expected in field culture; still they are doubtless fairly comparable the one with the other. The valuable characteristic of the legumes as "flesh-forming" foods is shown very clearly in the pounds of protein they afford per acre as compared with Indian corn and corn fodder.

TABLE 2.

YIELD PER ACRE OF LEGUMES IN THESE EXPERIMENTS.

Weights of crop as harvested, of dry substance and of ingredients of dry substance in crops, and weights of the same ingredients in crops of corn and timothy hay for comparison.

		WATER-FREE SUBSTANCE (DRY MATTER). ACTUAL NUTRIENTS.				
			NUTRITIVE INGREDIENTS.			
	Green Crop.	Total Dry Matter.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.
	Tons.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Horse bean, past bloom, - -	17.5	5800	1073	181	2065	1923
Soja bean, seeds nearly grown, -	9.5	5000	1033	426	2039	990
Cow pea, vines, - - - - -	8.0	3000	418	76	1449	679
Vetch in bloom, - - - -	12.0	4800	954	99	1553	1451
White lupine, nearly past bloom,	12.0	3500	542	83	1249	1222
Yellow lupine, past full bloom, -	23.0	5000	831	113	1958	1575
Blue lupine, nearly past bloom, -	20.0	5300	795	119	2099	1675
Clover, in full bloom, - - -	13.0	4900	862	146	1968	1443
Corn, 50 bushels at harvest and two tons of stover, - -		4100	376	155	2687	734
Timothy hay, 3 tons per acre, -		5400	369	127	2821	1822

In order to compare the value of the different legumes, without regard to yield per acre, there are given in Table 3, which follows, the pounds of dry matter, protein, fat, nitrogen-free extract and fiber in one ton of green crop. The soja bean is omitted, as it was so much farther advanced at harvesting than the others that it is not comparable with them.

TABLE 3.

NUTRITIVE INGREDIENTS IN ONE TON (2,000 lbs.) OF SOME LEGUMES.

	Dry Matter.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Horse bean, past bloom, - - -	331	61	10	118	109
Cow pea, - - - - - - -	375	52	9	181	85
Vetch, in bloom, - - - - -	400	79	8	128	121
White lupine, nearly past bloom, - -	291	45	7	104	102
Yellow lupine, past full bloom, - -	218	37	5	85	68
Blue lupine, nearly past bloom, - -	265	40	6	105	84
Clover, in full bloom, - - - -	377	66	11	151	111

MANURIAL VALUE OF LEGUMINOUS CROPS.

TABLE 4.

FERTILIZING INGREDIENTS IN CROP AND ROOTS PER ACRE IN SOME LEGUMES.

	NITROGEN.			POTASH. (K_2O.)			PHOSPH'C ACID (P_2O_5.)		
	In Crop.	In Roots, etc.	Total.	In Crop.	In Roots, etc.	Total.	In Crop.	In Roots, etc.	Total.
Horse bean, past bloom, - -	171	32	**203**	153	20	**173**	30	6	**36**
Soja bean, seeds nearly grown,	165	9	**174**	109	6	**115**	42	2	**44**
Cow pea, - - - - -	67	23	**90**	60	15	**75**	17	6	**23**
Vetch in bloom, - - -	153	27	**180**	163	22	**185**	37	7	**44**
White lupine, nearly past bloom,	87	10	**97**	100	11	**111**	18	2	**20**
Yellow lupine, past full bloom, -	133	16	**149**	149	22	**169**	27	6	**33**
Blue lupine, nearly past bloom,	127	11	**138**	160	19	**179**	32	3	**35**
Red clover, in full bloom, -	138	44	**152**	152	32	**184**	32	13	**45**
FERTILIZERS.									
One ton rich stable manure, -			**10**			**8**			**10**
100 pounds nitrate of soda, -			**16**			—			—
100 pounds dissolved bone-black,			—			—			**16**
100 pounds ground bone, - -			**3**			—			**22**
100 pounds muriate of potash, -			—			**50**			—

Besides the food value of a feeding stuff, its manurial value is important. The plant contains the nitrogen, phosphoric acid, potash, lime, and other ingredients of plant food. If all the manure, both liquid and solid, is carefully preserved, it will contain four-fifths of the nitrogen or thereabouts, and nearly all of the phosphoric acid and potash that was in the food eaten by the animals.

In Table 4, on preceding page, the pounds of nitrogen, potash, and phosphoric acid furnished by a crop of legumes as grown by the Station are given. The yield per acre is assumed to be as found in the experimental plots. Under each fertilizing constituent is given the number of pounds per acre removed in the crop, the number of pounds left behind in roots and stubble, and the total found in crop, stubble, and roots.

GREEN MANURING.

While it is generally better to feed a crop than to plow it under, there are some crops, as lupines, that may at times be used to good advantage for green manure. Soils that refuse to grow clover will sometimes give good crops of lupines, which may secure a large amount of their nitrogen from the air. The white lupine grown by the Station (see Table 4), though yielding an unusually small crop, contained per acre in its tops and roots as much nitrogen as 600 pounds of nitrate of soda, as much potash as 200 pounds of muriate of potash, and more phosphoric acid than 100 pounds of dissolved bone-black. While nitrogen in the form of decaying organic matter is not so readily available as that of nitrate of soda, and for immediate use would not be as valuable, yet it stays longer in the soil and its effect is more enduring. The use of such plants on light soils naturally deficient in organic matter and in nitrogen for green manuring, is a subject worthy of careful consideration and trial.

A shrewd and successful farmer in this State was wont to say, "the cheapest manure I can buy is clover seed." Why clover makes such cheap and valuable manure, this BULLETIN has attempted to explain. It is important for Connecticut farmers to consider whether they may not profitably grow other legumes as well as clover, and thus increase the number of plants to furnish the nutritive materials which make meat and milk and which are lacking in hay, corn fodder, corn stalks and stover, and at the same time make cheap manure to bring up their exhausted soils. For old pastures and worn out mowing lands they in many cases prove extremely valuable.

SUMMARY.

In order to make the best hay it is necessary to cut the grass at the proper degree of maturity. It is difficult to do this when too heavy an acreage of any one species is grown, and on this account it is advantageous to grow grasses maturing at different times. In the experiments by the Station here reported, the most promising appear to be orchard grass, tall meadow fescue grass, tall meadow oat grass, fowl meadow grass, and perennial rye grass. The importance of obtaining pure seed can hardly be over estimated. Farmers are recommended to try small plats of some of these grasses and discover for themselves their adaptability to their own needs.

The legumes are especially valuable because of:—

1. Their large percentages of protein compounds which serve to form blood, muscle, bone and milk, and their consequent feeding value, which exceeds that of the grasses, corn fodder, corn stover, or straws. They may be used to supplement these fodders in place of the concentrated nitrogenous feeds, such as bran, cotton seed, linseed, and gluten meals, etc. Hay from the legumes is twice or more than twice as rich in protein as that from the grasses.

2. Their power of gathering large quantities of plant food from natural sources. Many, if not all of our common legumes acquire considerable quantities of nitrogen from the air. Their roots penetrate deeply into the subsoil, and they thus obtain plant food from depths beyond the reach of plants with smaller root development.

3. Their manurial value. When the crop is fed, most of the nitrogen, phosphoric acid, potash and other fertilizing ingredients go into the excrement, liquid and solid, and if preserved, make a rich manure. If the crop is plowed under, its plant food, including that acquired from the air and gathered from the subsoil, becomes available for succeeding crops. The large amounts of plant food left behind in roots and stubble after the removal of the crop, furnish a cheap and valuable store of plant food for following crops.

While the clovers will doubtless prove in the future, as they have in the past, the most valuable of the legumes for general purposes in Connecticut, the cow pea, soja bean, and vetches are valuable for forage, silage or hay, and the experiments and observations at the Station and elsewhere indicate that they are worthy of careful trial.

CHARLES D. WOODS, *Chemist.* *
C. S. PHELPS, *Agriculturist.*

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* In the absence of the Director of the Station, Prof. W. O. Atwater, who is engaged in the duties of Director of the Office of Experiment Stations of the Department of Agriculture in Washington, the Chemist of the Station serves as Acting Director.

STORRS SCHOOL
Agricultural Experiment Station,
STORRS, CONN.

BULLETIN No. 7.—SEPTEMBER, 1891.

CHEMISTRY AND ECONOMY OF FOOD.

BY W. O. ATWATER AND CHAS. D. WOODS.

Food constitutes the chief item of the living expenses of the people, of our agricultural production, and of our export to Europe. Wage-workers and people of moderate incomes generally spend, and must spend, more than half their earnings for food. They do not understand either the relation of the nutritive value of food to its cost, or its physiological effects. The result is great waste in the purchase and use of food, loss of money, and injury to health.

The agricultural production of the United States is one-sided. Our food supply for man and beast contains an excess of the materials which make fat and serve the body for fuel, and are relatively deficient in the nitrogenous compounds which make blood, muscle, and bone. The farmer loses because his products do not fit the demands of the home and foreign markets. At the same time, our national dietary has become one-sided, so that though we live upon a high nutritive plane, our food might be better fitted to our needs.

The object of the present BULLETIN is to state briefly the main results of some inquiries regarding food, the detailed accounts of which are to be published in the Annual Report of the Station for 1891. In the very brief space here allowed, little more can be done than call attention to the main facts.*

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* Those who are interested can obtain the Report, which will be issued probably some time in March, 1892, and will be bound in the same volume with the Report of the Conn. State Board of Agriculture for 1892. The article will include results of investigations carried on during a number of years past in this laboratory, in connection with the Smithsonian Institution and the U. S. Department of Labor, as well as the work of the Station.

THE NUTRITIVE INGREDIENTS OF FOOD.

A pound of lean beef and a quart of whole milk contain about the same amounts of actually nutritive material. But the pound of beef costs more than the quart of milk, and its nutrients differ not only in number and kind, but are, for ordinary use, more valuable than those of the milk. This illustrates a fundamental fact in the economy of foods, namely, that the differences in the values of different foods depend upon both the kinds and the amounts of the nutritive materials which they contain. Add to this that it is essential for health that the food shall supply the nutrients in the kinds and the proportions required by the body, and that it is likewise important, from a pecuniary standpoint, that the materials be obtained at the minimum cost, and we have the fundamental principles of food economy.

Twenty years ago comparatively little was known about these things, and even to-day our knowledge of them is far from complete, but still we know the proportions of the different nutritive ingredients in our ordinary food materials; we have a reasonably clear conception of their uses in the nutrition of our bodies, and a large amount of observation and experiment has indicated about what proportions of the different classes of nutrients are required to meet the needs of people in different classes of life.

The greater part of this definite knowledge comes from chemical studies of food materials and from experiments in which living animals are supplied with foods of various kinds and the effects noted. The food, the excrement, both solid and liquid, and in some cases the inhaled and exhaled air, are measured, weighed, and analyzed. Many trials have been made with domestic animals and a large number also with human beings of both sexes and different ages. The best investigation in this line has been done during the last twenty years,—nearly all of it in Europe, and the larger share in Germany.

Within a few years numerous feeding tests and digestion experiments made in this country have contributed to the knowledge of the effects of foods upon domestic animals, but thus far very little has been done here in the study of the nutrition of man. Chemical analyses of many of the vegetable foods used by man have been made by experiment stations, though these have been undertaken primarily to ascertain their feeding values for animals. Not far from fifty dietaries of several hundred people in private families and boarding-houses, mostly in New England, have been collated, and the chemical analysis of quite a large number of animal foods—meat, fish, oysters, and the like—have been made in the chemical laboratory of Wesleyan University, and by this Station, since 1880.

The chemical composition of foods is compiled from American analyses. The digestion experiments are wholly European, and the dietaries are both American and European.

COMPOSITION OF FOOD MATERIALS.—NUTRIENTS AND THEIR FUNCTIONS IN NUTRITION.

Ordinary food materials, such as meat, fish, eggs, potatoes, wheat, etc., consist of:

Refuse.—As the bones of meat and fish, shells of shell-fish, skin of potatoes, bran of wheat, etc.

Edible portion.—As the flesh of meat and fish, the white and yolk of eggs, wheat flour, etc. The edible portion consists of:

Water and nutritive ingredients or nutrients.

The principal kinds of nutritive ingredients are:

Protein, fats, carbohydrates, and mineral matters.

The water, refuse, and salt of salted meat and fish, are called non-nutrients. The water contained in food and beverages has the same composition and properties as other water. It is, of course, indispensable for nourishment, but is not a nutrient in the same sense in which the word is here used. In comparing the values of different food materials for nourishment, the refuse and water are left out of account.

CLASSES OF NUTRIENTS.

The following are familiar examples of compounds of each of the four principal classes of nutrients:

Protein, - -	Albuminoids: *e. g.*, albumen (white of eggs); casein (curd) of milk; myosin, the basis of muscle (lean meat); gluten of wheat, etc.
	Gelatinoids: *e. g.*, collagen of tendons; ossein of bones; which yield gelatin or glue, etc.
	Meats and fish contain very small quantities of so-called "extractives." They include kreatin and allied compounds, and are the chief ingredients of beef-tea and meat-extract. They contain nitrogen, and hence are commonly classed with protein.
Fats, - -	*e. g.*, fat of meat; fat (butter) of milk; olive oil; oil of corn, wheat, etc.
Carbohydrates, -	*e. g.*, sugar, starch, cellulose (woody fiber), etc.
Mineral Matters,	*e. g.*, calcium phosphate or phosphate of lime, sodium chloride (common salt), etc.

It is to be especially noted that the protein compounds contain nitrogen, while the fats and carbohydrates have none. The albuminoids and gelatinoids are frequently classed together as proteids.

POTENTIAL ENERGY OF FOOD.*

In being consumed in the body as fuel to furnish heat and muscular energy, the nutrients appear to replace one another in proportion to their potential energy, which is accordingly taken as a measure of their fuel value. The energy is estimated in Calories. The Calorie is the heat which would raise a kilogram of water one degree centigrade (or one pound of water about four degrees Fahrenheit). A foot-ton is the energy (power) which would lift one ton one foot. One Calorie corresponds to 1.53 foot-tons. A gram of protein or a gram of carbohydrates is assumed to yield 4.1, and a gram of fat 9.3 Calories. A given weight of fat is thus taken to be equivalent in fuel value, on the average, to a little over twice the same weight of protein or carbohydrates. The figures for potential energy in table 1 are calculated for each food material by multiplying the number of grams of protein and of carbohydrates in one pound (1 lb. equals 453.6 grams) by 4.1, and the number of grams of fat by 9.3, and taking the sum of these three products as the number of Calories of potential energy in a pound of the material.

Tables 1 and 2, showing the composition of animal foods and the constituents of vegetable foods, follow.

The last column in each of these tables gives the number of Calories in one pound of each food material. These are estimated from the chemical composition as indicated above. These Calories of potential energy indicate the fuel value of the food, or, in other words, its capacity for yielding heat to keep the body warm and to give muscular strength for work.

Table 1 gives the chemical composition, including both edible portion and refuse. It is interesting to note in this table the difference in the amounts of refuse and edible portion in the different kinds of meats, fish, etc., as they are ordinarily found in the markets. In some specimens of meats, as round steak, the bone and other inedible portions are less than one-tenth of the whole, whereas in the flounder the refuse amounts to two-thirds and the edible portion to only one-third of the whole.

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* This subject is discussed in the Report of the Station for 1890, pp. 174–181.

TABLE 1.

Percentages of Nutrients (Nutritive Ingredients), Water, and Refuse, and Estimated Potential Energy (Fuel Value) in Specimens of Food Materials as Purchased.

FOOD MATERIALS.	Number of Analyses.	Refuse (Bones, Skin, Shell, etc.)	EDIBLE PORTION.						
			Water.	NUTRIENTS.					Potent'l Energy in one pound.
				Total.	Protein.	Fat.	Carbo-hydrates.	Mineral Matters.	
		%	%	%	%	%	%	%	Cal.
Beef—Neck,	3	20.0	49.6	30.4	15.6	14.0	—	0.8	880
Shoulder,	6	12.6	55.8	31.6	17.0	13.7	—	0.9	895
Chuck rib,	8	14.6	49.5	35.9	15.0	20.1	—	0.8	1125
Rib,	4	21.0	38.2	40.8	12.2	27.9	—	0.7	1405
Sirloin,	4	19.5	48.3	32.2	15.0	16.4	—	0.8	970
Round steak,	1	7.8	60.9	31.3	18.0	12.3	—	1.0	855
Fore quarter,	—	18.5	44.1	37.4	14.1	22.5	—	0.8	1210
Hind quarter,	—	20.2	44.4	35.4	13.6	21.0	—	0.8	1140
Side, without kidney fat,	—	19.2	44.3	36.5	13.9	21.8	—	0.8	1180
Rump, corned,	1	5.0	70.8	24.2	16.7	5.1	—	2.4	525
Flank, corned,	2	12.1	43.7	44.2	12.4	29.2	—	2.6	1460
Veal—Shoulder,	2	17.9	56.7	25.4	16.6	7.9	—	0.9	640
Mutton—Shoulder,	1	16.3	49.0	34.7	15.1	18.8	—	0.8	1075
Leg,	1	18.1	50.6	31.3	15.0	15.6	—	0.7	935
Loin,	1	15.8	41.5	42.7	12.6	29.5	—	0.6	1480
Fore quarter,	—	19.0	42.3	38.7	13.7	24.2	—	0.8	1275
Hind quarter,	—	15.7	46.1	38.2	14.3	23.2	—	0.7	1245
Side, without kidney fat,	—	17.3	44.2	38.5	14.0	23.7	—	0.8	1260
Lamb—Shoulder,	1	20.3	39.6	37.1	13.5	22.8	—	0.8	1255
Leg,	1	17.7	53.3	29.0	15.5	12.6	—	0.9	820
Loin,	1	12.2	48.1	39.7	16.7	22.1	—	0.9	1245
Fore quarter,	—	18.8	44.7	36.5	14.7	21.0	—	0.8	1160
Hind quarter,	—	15.7	51.3	33.0	16.0	16.1	—	0.9	975
Side, without kidney fat,	—	17.3	47.9	34.8	15.3	18.6	—	0.9	1070
Pork—Shoulder roast, fresh,	4	14.6	43.0	42.4	13.6	28.0	—	0.8	1435
Ham, salted, smoked,	1	11.4	36.8	51.8	14.8	34.6	—	2.4	1735
Chicken,	1	38.2	44.6	17.2	15.1	1.2	—	0.9	330
Turkey,	1	32.4	44.7	22.9	16.1	5.9	—	0.9	550
Eggs, in shell,	2	13.7	63.1	23.2	12.1	10.2	—	0.9	655
Fish, etc.—Flounder, whole,	1	66.8	27.2	6.0	5.2	0.3	—	0.5	110
Haddock, dressed,	4	51.0	40.0	9.0	8.2	0.2	—	0.6	160
Bluefish, dressed,	3	48.6	40.3	11.1	9.8	0.6	—	0.7	210
Brook trout, whole,	3	48.1	40.4	11.5	9.8	1.1	—	0.6	230
Codfish, dressed,	3	29.9	58.5	11.6	10.6	0.2	—	0.8	205
Whitefish, whole,	1	53.5	32.5	14.0	10.3	3.0	—	0.7	320
Shad, whole,	7	50.1	35.2	14.7	9.2	4.8	—	0.7	375
Turbot, whole,	1	47.7	37.3	15.0	6.8	7.5	—	0.7	445
Mackerel, whole, lean,	1	38.3	48.5	13.2	11.2	1.4	—	0.6	265
Mackerel, whole, fat,	1	33.8	42.4	23.8	12.1	10.7	—	1.0	675
Mackerel, whole, average,	5	44.8	40.4	15.0	10.0	4.3	—	0.7	365
Halibut, dressed,	3	17.7	61.9	20.4	15.1	4.4	—	0.9	465
Salmon, whole,	4	35.3	40.6	24.1	14.3	8.8	—	1.0	635
Eel,	2	36.0	33.8	30.2	8.6	21.0	—	0.6	1045
Salt codfish,	2	42.1	40.3	17.6	16.0	0.4	—	1.2	315
Smoked herring,	1	50.9	19.2	29.9	20.2	8.8	—	0.9	745
Salt mackerel,	2	40.4	28.1	31.5	14.7	15.1	—	1.7	910
Canned salmon,	2	4.9	59.3	35.8	19.3	15.3	—	1.2	1005
Canned sardines,	1	5.0	53.6	41.4	24.0	12.1	—	5.3	955
Lobsters,	—	62.1	31.0	6.9	5.5	0.7	0.1	0.6	135
Oysters,	—	82.3	15.4	2.3	1.1	0.2	0.6	0.4	40

TABLE 2.

Percentages of Nutrients (Nutritive Ingredients), Water, etc., and Estimated Potential Energy, in Edible Portion of Specimens of Food Materials.

FOOD MATERIALS.	Number of Analyses.	Water.	NUTRIENTS.					Potential Energy in one pound.
			Total.	Protein.	Fat.	Carbohydrates.	Mineral Matters.	
		%	%	%	%	%	%	Cal.
Beef—Neck,	3	62.0	38.0	19.5	17.5	—	1.0	1100
Shoulder,	6	63.9	36.1	19.5	15.6	—	1.0	1020
Chuck rib,	8	58.0	42.0	17.6	23.5	—	0.9	1320
Rib,	5	48.1	51.9	15.4	35.6	—	0.9	1790
Sirloin,	4	60.0	40.0	18.5	20.5	—	1.0	1210
Round,	3	68.2	31.8	20.5	10.1	—	1.2	805
Fore quarter,	—	54.1	45.9	17.3	27.7	—	0.9	1490
Hind quarter,	—	55.7	44.3	17.1	26.3	—	0.9	1430
Side, without kidney fat,	—	54.8	45.2	17.2	27.1	—	0.9	1465
Rump, corned,	1	58.1	41.9	13.3	26.6	—	2.0	1370
Flank, corned,	2	49.8	50.2	14.2	33.0	—	3.0	1655
Corned, canned,	2	52.8	47.2	26.7	17.1	—	3.4	1220
Salted, dried,	2	58.6	41.4	28.8	4.4	1.4	6.8	745
Tongue, corned,	1	63.5	26.5	17.4	18.0	—	1.1	1085
Liver,	1	69.5	30.5	20.1	5.4	3.5	1.5	665
Tripe, soused,	1	84.0	16.0	13.9	1.8	—	0.3	335
Veal—Shoulder,	2	68.8	31.2	20.2	9.8	—	1.2	790
Mutton—Shoulder,	1	58.6	41.4	18.1	22.4	—	0.9	1280
Leg,	1	61.8	38.2	18.3	19.0	—	0.9	1140
Loin,	1	49.3	50.7	15.0	35.0	—	0.7	1755
Fore quarter,	—	55.2	47.8	17.0	29.9	—	0.9	1580
Hind quarter,	—	54.7	45.3	16.9	27.5	—	0.9	1475
Side, without kidney fat,	—	53.5	46.5	16.9	28.7	—	0.9	1525
Lamb—Shoulder,	1	51.8	48.2	17.5	29.7	—	1.0	1580
Leg,	1	64.7	35.3	18.9	15.3	—	1.1	1000
Loin,	1	54.8	45.2	19.0	25.1	—	1.1	1410
Fore quarter,	—	55.1	44.9	18.1	25.8	—	1.0	1425
Hind quarter,	—	60.9	39.1	18.9	19.1	—	1.1	1155
Side, without kidney fat,	—	57.9	42.1	18.6	22.5	—	1.0	1295
Pork—Shoulder roast, fresh,	4	50.3	49.7	16.0	32.8	—	0.9	1680
Ham, salted, smoked,	1	41.5	58.5	16.7	39.1	—	2.7	1960
Fat, salted,	1	12.1	87.9	0.9	82.8	—	4.2	3510
Sausage—Pork,	2	41.2	58.8	13.8	42.8	—	2.2	2065
Bologna,	1	62.4	37.6	18.8	15.8	—	3.0	1015
Chicken,	1	72.2	27.8	24.4	2.0	—	1.4	540
Turkey,	1	66.2	33.8	23.9	8.7	—	1.2	810
Eggs,	27	73.8	26.2	14.9	10.5	—	0.8	721
Milk,	—	87.0	13.0	3.6	4.0	4.7	0.7	325
Butter,	—	10.5	89.0	1.0	85.0	0.5	3.0	3615
Oleomargarine,	—	11.0	89.5	0.6	85.0	0.4	3.0	3605
Cheese—Full cream,	5	30.2	69.8	28.3	35.5	1.8	4.2	2070
Skim-milk,	1	41.3	58.7	38.4	6.8	8.9	4.6	1165
Fish—Flounder,	2	84.2	15.8	13.8	0.7	—	1.3	285
Haddock,	4	81.7	18.3	16.8	0.3	—	1.2	325
Bluefish,	1	78.5	21.5	19.0	1.2	—	1.3	405
Brook trout,	3	77.7	22.3	19.0	2.1	—	1.2	440
Codfish,	5	82.6	17.4	15.8	0.4	—	1.2	310
Whitefish,	1	69.8	30.2	22.1	6.5	—	1.6	685
Shad,	7	70.6	29.4	18.6	9.5	—	1.3	745
Turbot,	1	71.4	28.6	12.9	14.4	—	1.3	850

TABLE 2.—(*Continued.*)

Percentages of Nutrients (Nutritive Ingredients), Water, etc., and Estimated Potential Energy in Edible Portion of Specimens of Food Materials.

FOOD MATERIALS.	Number of Analyses.	Water.	NUTRIENTS.					Potential Energy in one pound.
			Total.	Protein.	Fat.	Carbohydrates.	Mineral Matters.	
		%	%	%	%	%	%	Cal.
Fish—Mackerel, lean,	1	78.7	21.3	18.1	2.2	—	1.0	430
Mackerel, fat,	1	64.0	36.0	18.2	16.3	—	1.5	1025
Mackerel, average,	7	73.4	26.6	18.2	7.1	—	1.3	640
Halibut,	3	75.4	24.6	18.3	5.2	—	1.1	560
Salmon,	5	63.6	36.4	21.6	13.4	—	1.4	965
Salt cod,	2	53.6	—	21.4	0.3	—	1.6	410
Herring, salt,	1	34.6	—	36.4	15.8	—	1.5	1345
Mackerel, salt,	1	43.4	—	17.3	26.4	—	2.6	1860
Oysters, lean,	—	90.9	9.1	4.2	0.6	1.8	2.5	135
Oysters, fat,	—	81.7	18.3	8.0	1.7	6.7	1.9	345
Oysters, average,	—	87.1	12.9	6.0	1.2	3.7	2.0	230
Wheat flour,	22	12.5	87.5	11.0	1.1	74.9	0.5	1644
Graham flour (wheat),	3	13.1	86.9	11.7	1.7	71.7	1.8	1625
Cracked wheat,	2	10.4	89.6	11.9	1.7	74.6	1.4	1680
Rye flour,	4	13.1	86.9	6.7	0.8	78.7	0.7	1625
Buckwheat flour,	4	14.6	85.4	6.9	1.4	76.1	1.0	1605
Oatmeal,	8	7.6	92.4	15.1	7.1	68.2	2.0	1850
Maize meal (corn meal),	77	15.0	85.0	9.2	3.8	70.6	1.4	1645
Rice,	10	12.4	87.6	7.4	0.4	79.4	0.4	1630
Peas,	4	12.3	87.7	26.7	1.7	56.4	2.9	1565
Beans,	3	12.6	87.4	23.1	2.0	59.2	3.1	1615
Potatoes,	12	78.9	21.1	2.1	0.1	17.9	1.0	375
Sweet potatoes,	6	71.1	28.9	1.5	0.4	26.0	1.0	530
Turnips,	7	89.4	10.6	1.2	0.2	8.2	1.0	185
Beets,	9	88.5	11.5	1.5	0.1	8.9	1.0	195
Carrots,	8	88.6	11.4	1.1	0.4	8.9	1.0	200
Parsnips,	1	80.3	19.7	1.3	0.7	16.2	1.5	355
Onions,	6	87.6	12.4	1.4	0.3	10.1	0.6	225
String beans,	2	87.2	12.8	2.2	0.4	9.4	0.8	235
Green peas,	1	78.1	21,9	4.4	0.6	16.0	0.9	405
Green corn,	1	81.3	18.7	2.8	1.1	13.2	0.6	345
Tomatoes,	6	96.0	4.0	0.8	0.4	2.5	0.3	80
Cucumbers,	2	96.0	4.0	0.8	0.2	2.5	0.5	70
Cabbage,	3	91.9	8.1	2.1	0.3	5.5	1.1	155
Squash,	9	81.4	18.6	3.0	2.4	12.1	1.1	380
Pumpkin,	6	85.5	14.5	3.2	2.5	7.6	1.2	305
Asparagus,	3	94.0	6.0	1.8	0.3	3.2	0.7	115
Apples,	2	83.2	16.8	0.2	0.4	15.9	0.3	315
Starch,	2	2.0	98.0	—	—	97.8	0.2	1820
Sugar, granulated,	—	2.0	98.0	—	—	97.8	0.2	1820
Molasses,	—	24.6	75.4	—	—	73.1	2.3	1360
White bread (wheat),	5	32.3	67.7	8.8	1.7	56.3	0.9	1280
Graham bread (wheat),	1	34.2	65.8	9.5	1.4	53.3	1.6	1225
Rye bread,	1	30.0	70.0	8.4	0.5	59.7	1.4	1285
Boston crackers,	1	8.3	91.7	10.7	9.9	68.7	2.4	1895
Soda crackers,	1	8.0	92.0	10.3	9.4	70.5	1.8	1900
Oyster crackers,	1	3.8	96.1	11.3	4.8	77.5	2.5	1855
Oatmeal crackers,	1	4.9	95.1	10.4	13.7	69.6	1.4	2065
Graham crackers,	1	5.0	95.0	9.8	13.6	69.7	1.9	2050

In table 2 (pp. 6, 7), which gives the percentages of nutrients in the edible portions of foods, it is interesting to note the wide variations in the proportions of water and of nutrients. In general, the animal substances contain the most water and the vegetable foods the most nutrients, though potatoes and turnips and allied green vegetables are exceptions. Meats have more water in proportion as they have less fats. Thus very lean beef is nearly three-fourths water, while other and fatter cuts are less than one-half water. The flesh of fish is in general more watery than that of ordinary meats. Flour and meal have very little water, and sugar almost none. In examining the proportions of individual nutrients, the most striking fact is the difference between the meats and the fish, on one hand, and the vegetable foods on the other hand. The vegetable foods are rich in carbohydrates, and the meats abound in protein and fats, of which the vegetable foods usually have but little. Beans and oatmeal, however, are rich in protein, while fat pork has very little.

Uses of Food in the Body.

Food supplies the wants of the body in several ways. It either:

1. Is used to form the tissues and fluids of the body;
2. Is used to repair the wastes of tissues;
3. Is stored in the body for future consumption;
4. Is consumed as fuel, its potential energy being transformed into heat or muscular energy or other forms of energy required by the body; or,
5. In being consumed protects tissues or other food from consumption.

Ways in which Materials are used in the Body.

Protein forms tissue (muscle, tendon, etc., and fat) and serves as fuel.	Yield energy in form of heat and muscular strength.
Fats form fatty tissue (not muscle, etc.,) and serve as fuel.	
Carbohydrates are transformed into fat and serve as fuel.	

In being themselves burned to yield energy, the nutrients protect each other from being consumed. The protein and fats of body-tissue are used like those of food. An important use of the carbohydrates and fats is to protect protein (muscle, etc.) from consumption.

DIGESTIBILITY OF FOODS.

The question of the digestibility of foods is very complex and difficult. The ease of digestion of a given kind of food and its suitableness to the digestive organs vary greatly with different people, so that it is impossible to lay down hard and fast rules. The amounts digested are capable of a more nearly accurate determination. The method consists in weighing and analyzing both the food consumed and the intestinal excrement, which latter represents the amount of food undigested. The difference is the amount digested.

Such experiments upon human subjects are, however, much more difficult than digestion experiments with domestic animals, because of the necessity of avoiding complex mixtures of food in order that the digestibility of each particular food or food ingredient may be determined, and because of the fact that it is not easy to continue to eat the same kind of food long enough for a satisfactory experiment. In table 3, which follows, and which attempts to epitomize the results of about sixty experiments, mostly with men, more reliance can be placed upon the digestion co-efficients of animal than upon those of the vegetable foods. The figures showing the digestibility of the protein of the vegetable foods are nearly accurate, those of the carbohydrates reasonably so, and those of the fats least reliable and in some cases of very little value.

TABLE 3.

Digestibility of Nutrients of Food Materials.

ANIMAL FOODS.	PERCENTAGES DIGESTED.			VEGETABLE FOODS.	PERCENTAGES DIGESTED.		
	Protein.	Fat.	Carbohydrates.		Protein.	Fat.	Carbohydrates.
	%	%	%		%	%	%
Beef and veal, - -	100	95	—	Wheat flour, fine, -	85	80 % assumed for all.	95 % assumed for all.
Mutton, - - -	100	95	—	Wheat flour, medium,	81		
Pork, - - -	100	95	—	Wheat flour, coarse, -	75		
Fish and oysters, -	100	95	—	Rice, - - -	85		
Milk, - - -	100	96	100	Macaroni, - -	85		
Cheese, - - -	100	95	100	Rye flour, - -	78		
Butter, - - -	—	96	—	Maize meal, - -	85		
Oleomargarine, - -	—	95	—	Potatoes, - - -	75		
Tallow, - - -	—	95	—	Cabbages, turnips, etc.,	80		
Lard, - - -	—	95	—	Beans, - - -	85		
Oils, - - - -	—	95	—	Peas, - - -	85		
Eggs, - - -	100	98	—				

Table 4, which follows, containing the proportions of nutrients digested and not digested from food materials by men, was computed by applying the data obtained in the digestion experiments epitomized in table 3 to some of those of the composition of food materials in table 2.

TABLE 4.

Proportions of Nutrients Digested and not Digested from Food Materials by Healthy Men.

FOOD MATERIALS.	PROTEIN.			FATS.			CARBO-HYDRATES.		
	Digested.	Undigested.	Total.	Digested.	Undigested.	Total.	Digested.	Undigested.	Total.
	%	%	%	%	%	%	%	%	%
Beef, shoulder,	19.5	—	19.5	14.8	.8	15.6	—	—	—
Beef, sirloin,	18.5	—	18.5	19.5	1.0	20.5	—	—	—
Beef, round,	20.5	—	20.5	9.6	.5	10.1	—	—	—
Veal, shoulder,	20.2	—	20.2	9.3	.5	9.8	—	—	—
Mutton, shoulder,	18.1	—	18.1	21.3	1.1	22.4	—	—	—
Mutton, loin,	15.0	—	15.0	33.3	1.7	35.0	—	—	—
Pork, shoulder,	16.0	—	16.0	31.2	1.6	32.8	—	—	—
Pork, very fat,	.9	—	.9	78.7	4.1	82.8	—	—	—
Eggs,	14.9	—	14.9	10.3	.2	10.5	—	—	—
Milk,	3.6	—	3.6	3.8	.2	4.0	4.7	—	4.7
Butter,	?	?	1.0	81.6	3.4	85.0	.5	—	.5
Cheese, full cream,	28.3	—	28.3	33.7	1.8	35.5	1.8	—	1.8
Cheese, skim milk,	38.4	—	38.4	6.5	.3	6.8	8.9	—	8.9
Haddock,	16.8	—	16.8	.3	—	.3	—	—	—
Bluefish,	19.0	—	19.0	1.1	.1	1.2	—	—	—
Cod,	15.8	—	15.8	.4	—	.4	—	—	—
Shad,	18.6	—	18.6	9.0	.5	9.5	—	—	—
Mackerel,	18.8	—	18.8	7.8	.4	8.2	—	—	—
Halibut,	18.3	—	18.3	4.9	.3	5.2	—	—	—
Salmon,	21.6	—	21.6	12.7	.7	13.4	—	—	—
Wheat flour, fine,	9.4	1.6	11.0	.9	.2	1.1	71.1	3.8	74.9
Wheat flour, medium,	9.5	2.2	11.7	1.4	.3	1.7	68.1	3.6	71.7
Cracked wheat,	8.9	3.0	11.9	1.4	.3	1.7	70.9	3.7	74.6
Maize meal,	7.8	1.4	9.2	3.0	.8	3.8	67.1	3.5	70.6
Rice,	6.3	1.1	7.4	.3	.1	.4	75.4	4.0	79.4
Potatoes,	1.6	.5	2.1	?	?	0.1	17.0	.9	17.9
Turnips,	1.0	.2	1.2	?	?	0.2	7.8	.4	8.2
Beets,	1.2	.3	1.5	?	?	0.1	8.5	.4	8.9
Wheat bread,	7.1	1.7	8.8	1.4	.3	1.7	53.4	2.8	56.2
Rye bread,	6.5	1.9	8.4	.4	.1	0.5	56.7	3.0	59.7
Graham bread,	7.1	2.4	9.5	1.1	.3	1.4	50.6	2.7	53.3

STANDARD DIETARIES.

The demands of different people for nutrients in their daily food vary with age, sex, occupation, and other conditions, including especially the widely differing characteristics of individuals.

The standards in table 5, herewith, are intended to represent roughly the needs of average individuals of the classes named.

[Nos. 1, 3, 4, 5, and 6 are as proposed by Voit and his followers of the Munich school of physiologists, and are based upon observations of quantities actually consumed in a considerable number of cases. Nos. 7 and 8 are by Voit, and based both upon quantities consumed by individuals under experiment and upon observed dietaries of a much larger number of persons in Germany. Nos. 9, 10, and 11 are by Playfair, and are based mainly upon observations of actual dietaries in England. No. 2 is calculated by the writers from the data and results used in Nos. 1 and 3. In Nos. 12, 13, 14, and 15, by one of us (W. O. A.), the data of Voit, Playfair, and other European observers are taken into account, but the conclusions are modified by the results of studies of a considerable number of dietaries of people in the United States.]

TABLE 5.

Standards for Daily Dietaries for People of Different Classes.

	NUTRIENTS.				Potential Energy of Nutrients.
	Protein.	Fat.	Carbo-hydrates.	Total.	
	*G	G	G	G	Cal.
1. Children, 1 to 2 years, *German*,	28	37	75	140	765
2. Children, 2 to 6 years, *German*,	55	40	200	295	1420
3. Children, 6 to 15 years, *German*,	75	43	325	443	2040
4. Aged woman, *German*,	80	50	260	390	1860
5. Aged man, *German*,	100	68	350	518	2475
6. Woman at moderate work, *German*,	92	44	400	536	2425
7. Man at moderate work, *German*,	118	56	500	674	3055
8. Man at hard work, *German*,	145	100	450	695	3370
9. Man with modeate exercise, *English*,	119	51	531	701	3140
10. Active laborer, *English*,	156	71	568	795	3630
11. Hard-worked laborer, *English*,	185	71	568	824	3750
12. Woman with light exercise, *American*,	80	80	300	460	2300
13. Man with light exercise, *American*,	100	100	360	560	2815
14. Man at moderate work, *American*,	125	125	450	700	3520
15. Man at hard work, *American*,	150	150	500	800	4060

*100 grams.=3.5 ounces, or .22 pounds. 1 oz.=28.35 g. 1 lb.=453.6 g.

ACTUAL DIETARIES OF DIFFERENT CLASSES OF PEOPLE.

Table 6 gives the quantities of nutrients and potential energy in a number of observed dietaries. The figures for European dietaries are mostly by Voit and his followers in Germany, and by Playfair in England. The American figures are by the writers; those for the army and navy rations are based upon the United States Regulations, the rest upon observations of actual dietaries.†

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† Comparison of the data of Tables 4, 5, and 6 implies that the food of people in this country is apt to be considerably in excess of the demands for nourishment. The excess is made up largely of meats, especially of the fatter kinds, and of sweetmeats, including sugar.

TABLE 6.

Nutrients and Potential Energy in Dietaries of Different People.

	NUTRIENTS.				Potential Energy of Nutrients.
	Protein.	Fats.	Carbohydrates.	Total.	
European and Japanese dietaries:	*G	G	G	G	Cal.
1. Sewing-girl, London—wages 93 cts. per week,	53	33	316	402	1820
2. Factory-girl, Leipsic, Germany — wages, $1.21 per week,	52	53	301	406	1940
3. Weaver, England—time of scarcity,	60	28	398	486	2140
4. Under-fed laborers, Lombardy, Italy,	82	40	362	484	2190
5. Trappist monk in cloister; very little exercise,	68	11	469	548	2305
6. Students, Japan,	97	16	438	551	2345
7. University professor, Munich, Germany,	100	100	240	440	2325
8. Lawyer, Munich,	80	125	222	427	2400
9. Physician, Munich,	131	95	327	553	2760
10. Painter, Leipsic, Germany,	87	69	366	522	2500
11. Cabinetmaker, Leipsic, Germany,	77	57	466	600	2755
12. "Fully-fed" tailors, England,	131	39	525	625	3055
13. "Well-paid" mechanic, Munich, Germany,	151	54	479	684	3085
14. Carpenter, Munich, Germany,	131	68	494	693	3195
15. "Hard-worked" weaver, England,	151	43	622	816	3570
16. Blacksmith, England,	176	71	667	914	4115
17. Miners at very severe work, Germany,	133	113	634	880	4195
18. Brickmakers (Italians at contract work, Munich,	187	117	675	959	4640
19. Brewery laborer, Munich, very severe work,	223	113	909	1245	5690
20. German soldiers, peace-footing,	114	39	480	633	2800
21. German soldiers, war-footing,	134	58	489	681	3095
22. German soldiers, Franco-German war, extraordinary ration,	157	285	331	773	4650
United States and Canadian dietaries:					
23. French-Canadian working people in Canada,	109	109	527	745	3620
24. French-Canadians, factory operatives, in Mass.	118	204	549	871	4630
25. Other factory operatives, mechanics, etc., Mass.	127	186	531	844	4430
26. Glassblowers, East Cambridge, Mass.,	95	132	481	705	3590
27. Factory operatives, boarding-house, Mass.,	114	150	522	786	4000
28*a*. Well-to-do private family, food purchased,	129	183	467	779	4145
28*b*. Conn. food eaten,	128	177	466	771	4080
29*a*. College students from food purchased,	161	204	680	1045	5345
29*b*. northern and eastern food eaten,	138	184	622	944	4825
30*a*. States; bdg.-club, two food purchased,	115	163	460	738	3875
30*b*. dietaries, same club, food eaten,	104	136	421	661	3415
31. College foot-ball team, food eaten,	181	292	557	1030	5740
32. Mechanics (machinists), Conn.,	105	147	399	651	3435
33. Machinist, Boston, Mass.,	182	254	617	1053	5640
34. Teamsters, marble-workers, etc., with hard work, Mass.,	254	363	826	1443	7805
35. Brickmakers, Mass.,	180	365	1150	1695	8850
36. U. S. army ration,	120	161	454	735	3850
37. U. S. navy ration,	143	184	520	847	5000

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* 100 grams. =3.5 ounces or .22 pounds. 1 ounce =28.35 g. 1 pound =453.6 g.

AMPLE NOURISHMENT.—WASTE OF FOOD.

Table 6 gives illustrations of the actual amounts of foods consumed by people in New England. In a large number of dietaries that have been examined the smallest number of Calories in the daily ration is 3,400, and the dietaries range from this up to over 8,000, while those of people in corresponding conditions in Europe range from 2,500 to 4,500, or thereabouts. Doubtless, one reason for the difference is that people in this country waste so much of their food, as is illustrated by the dietary of a boarding-house in Connecticut, in which the amount of material left uneaten in the kitchen and at the table was one-ninth of the whole.

People in this country are better fed, clothed, and housed than in Europe; they live on a higher plane physically and intellectually. Doubtless, this is part of the explanation of the fact that working people in this country do much more work than in Europe; but there is no question that many of us eat a great deal more than is necessary. Physicians tell us that overeating is the cause of a great deal of ill-health, and certainly the figures in table 6 would seem to imply there might be good ground for the assertion.

People in general are wasteful of their food in two ways. They pay needlessly high prices, on the false supposition that the costliest food is the most economical, and in general they buy more than is necessary. Part of the excess is simply thrown away, and part is used to the injury of health.

COST OF FOOD.

The cost of food is the principal item of the living expenses of the large majority of the people—of all, indeed, but the especially well to do. Thus statistics of the cost of living of families of working men in Massachusetts* showed that those with incomes of from $350 to $400 per year paid 64 per cent. of this for food, leaving out the cost of preparing it for the table. On incomes of from $750 to $1,200, 56 per cent. was spent for food. Although the cost of food is so great, and although the health and strength of all are so intimately connected with, and dependent upon, their diet, yet even the most intelligent people know less of the actual uses and values of their food for fulfilling its purposes than of almost any other of the necessities of life.

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* Report of the Bureau of Statistics of Labor of Massachusetts for 1884.

TABLE 7.

Amounts of Nutrients furnished for Twenty-five Cents in Food Materials at Ordinary Prices.

Food Materials.	Prices per Pound.	Twenty-five cents will pay for					
		Total Food Materials.	Nutrients.				Calories of Potential Energy.
			Total.	Protein.	Fats.	Carbo-hydrates.	
	Cents.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cals.
Beef, neck,	10	2.50	.95	.49	.43	—	2725
	8	3.13	1.19	.61	.55	—	3455
	6	4.17	1.58	.81	.73	—	4585
Beef, round,	20	1.25	.40	.26	.13	—	1030
	18	1.39	.44	.29	.14	—	1130
	15	1.67	.53	.34	.17	—	1350
Beef, sirloin,	25	1.00	.40	.19	.21	—	1240
	22	1.14	.46	.21	.23	—	1360
	20	1.25	.50	.23	.26	—	1525
Mutton, leg,	25	1.00	.38	.18	.19	—	1135
	22	1.14	.44	.21	.22	—	1320
	20	1.25	.48	.23	.45	—	2325
Pork, salted, fat,	15	1.67	1.47	.02	1.38	—	5860
	12	2.08	1.83	.02	1.72	—	7295
	10	2.50	2.20	.02	2.07	—	8770
Bluefish,	18	1.38	.30	.26	.02	—	570
	15	1.67	.36	.32	.02	—	680
	12	2.08	.45	.40	.03	—	870
Shad,	15	1.07	.32	.20	.10	—	80
	12	2.08	.62	.39	.20	—	1570
	10	2.50	.74	.47	.24	—	1885
Mackerel,	18	1.38	.37	.25	.10	—	887
	15	1.67	.44	.30	.12	—	1065
	10	2.50	.67	.46	.18	—	1615
Cod, fresh,	10	2.50	.76	.55	.16	—	1700
	8	3.13	.95	.69	.20	—	2125
	6	4.17	1.24	.91	.27	—	2830
Cod, salt,	8	3.13	.68	.67	.01	—	1415
	5	4.17	.90	.89	.00	—	1655
Oysters, 50c. per quart,	25	1.00	.13	.06	.01	.04	230
Oysters, 35c. per quart,	17.5	1.43	.18	.09	.02	.05	345
Butter,	35	.71	.64	.01	.60	.00	2550
	30	.83	.74	.01	.71	.00	3015
	25	1.00	.90	.01	.85	.01	3625
Cheese, whole milk,	18	1.38	.96	.40	.49	.02	2850
	15	1.67	1.17	.47	.59	.03	3420
	12	2.08	1.45	.59	.72	.04	4210
Milk, 8c. per quart,	4	6.25	.81	.23	.25	.29	2020
Milk, 6c. per quart,	3	8.33	1.08	.30	.33	.39	2675
Milk, 4c. per quart,	2	12.50	1.63	.46	.50	.59	4065
Eggs, 35c. per doz.,	25	1.00	.26	.15	.11	—	745
Eggs, 25c. per doz.,	18.2	1.37	.36	.20	.14	—	980
Eggs, 15c. per doz.,	11	2.27	.60	.34	.24	—	1645
Wheat flour,	4	6.25	5.47	.69	.07	4.68	10285
	3.5	7.14	6.25	.79	.08	5.35	11755
	3	8.33	7.29	.92	.09	6.24	13695
Maize (corn) meal,	3	8.33	7.08	.77	.32	5.88	13719
	1	16.67	14.20	1.53	.64	1.80	30820
Potatoes, $1.00 per bush.	1.7	14.70	3.10	.31	.02	3.10	6425
Potatoes, 80c. per bush.,	1.25	20.00	4.22	.42	.02	3.58	7525
Potatoes, 50c. per bush.,	0.85	29.40	6.20	.62	.03	15.26	11065

The figures in the table on the opposite page illustrate the costs of food and of food ingredients. In general, animal foods are much more expensive than vegetable foods. There is, however, a great deal of difference between the actual cost of nutritive materials in different meats, as the tables show.

Only a few of the more common food materials are included in table 7, and these are given at different prices in order to point out the fact that what may be a cheap food at one price may be a relatively dear food at another. Thus, eggs at 15 cents per dozen furnish more nutrients and energy for 25 cents than round of beef at 15 cents or sirloin at 20 cents per pound. At 25 cents per dozen, however, eggs furnish considerably less nutrients for 25 cents than is furnished by beef round at 20 cents per pound or beef sirloin at 25 cents.

SUMMARY.

The actually nutritive ingredients of food may be divided into four classes: protein, fats, carbohydrates, and mineral matters. Leaving water out of account, lean meat, white of egg, casein (curd) of milk, and gluten of wheat consist mainly of protein compounds. Butter and lard are mostly fats. Sugar and starch are carbohydrates.

The nutrients of animal foods consist mainly of protein and fats. Those of the vegetable foods are largely carbohydrates. The fatter kinds of meat and some species of fish, as salmon, shad, and mackerel, contain considerable quantities of fat. The lean kinds of meat, and such fish as cod and haddock, contain very little fat. Beans, peas, oatmeal, and some other vegetable foods contain considerable quantities of protein.

In being consumed in the body to furnish heat and muscular energy, the nutrients replace one another in proportion to their potential energy, and this is accordingly taken as the measure of their fuel value. This is usually estimated in Calories, although sometimes in foot-tons.

The different nutrients have different offices to perform in the nutrition of the body. The protein forms muscle, tendon, and tissues in general. The fats do not form muscle, etc., but do form fatty tissues. The carbohydrates may be transformed into fat. All three serve as fuel and yield energy in the form of heat and muscular strength.

The demands of different people for nourishment vary with age, sex, occupation, and other conditions of life. Health and pecuniary economy alike require that the diet should contain nutrients proportioned to the wants of the user.

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STORRS SCHOOL

Agricultural Experiment Station,

STORRS, CONN.

BULLETIN No. 8.—APRIL, 1892.

SUMMARY OF ANNUAL REPORT FOR 1891.

I. Food Investigations.—Nitrogen and the Farmer.
II. Forage Crops.
III. Nitrogen of the Air as Plant Food.
IV. Fertilizer Experiments on Grass.
V. Field Experiments with Fertilizers by Farmers.

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— — ——,* Storrs,	*Assistant in Farm Experiments.*

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* Temporarily vacant.

ANNOUNCEMENT.

The present Bulletin contains a summary of the investigations published in the Annual Report of the Station for 1891. That Report makes a volume of two hundred pages, and is bound with the Report of the Connecticut Board of Agriculture for 1891. It contains details of the experiments conducted by the Station during the year and general discussions of the results. As the separate edition of the Station Report is limited, an effort is here made to explain briefly the character of the principal inquiries and their practical application. By the circulation of a somewhat large edition of this Bulletin it is hoped to bring the fruits of the work of the Station to a greater number of readers than would otherwise be feasible.

Much of the experimental inquiry carried on by the Station is still incomplete and the results are reserved for future publication. Such is the case with a series of experiments upon the feeding of milch cows, which have been in operation for nearly two years. The investigations of the bacteria of milk, cream, and butter, of which accounts have been given in former reports, are being continued. It is hoped that the organisms concerned in the production of cheese may also be studied. The work with the calorimeter has likewise been continued, and two members of the Station staff have given especial attention to it during late visits to European laboratories. The investigation of the assimilation of the free nitrogen of the air has entered a new phase, and special apparatus is being devised for its prosecution.

While a variety of investigations are reported, it will be observed that the leading feature of the Bulletin is to set forth the need of more and cheaper nitrogen for the farmer. A most important resource for nitrogen is found in the cultivation of the "nitrogen collectors," such as clover, peas, beans, vetch, alfalfa, soja beans, cowpeas, and other legumes, which gather it from the air. We need more nitrogen in manures to make better crops, in plants to make better food for animals, and in both animal and vegetable products to make more and better food for man.

W. O. ATWATER, *Director.*

FOOD INVESTIGATIONS. NITROGEN AND THE FARMER.

W. O. ATWATER AND C. D. WOODS.

The Annual Report of the Station contains accounts of investigations of amounts and composition of the food used by nearly fifty private families and boarding houses, mostly in New England, and chemical analyses of several hundred specimens of food materials of the kinds used. The people whose food consumption has thus been studied, the larger number of whom were wage-workers, numbered over one thousand.* Some of the inferences, including those which bear more especially upon the agricultural phases of the subject, are given herewith.

The most important conclusion for the practical farmer is the importance of making better use of the nitrogen which nature places at his disposal. Our grasses and grains have less nitrogen than they ought to have and would have with better manuring and culture. In consequence, the food of our domestic animals is not such as is best or most profitable, and, finally, the food which we ourselves consume is relatively deficient in nitrogenous ingredients. The farmers of Connecticut expend many thousands of dollars annually for nitrogen in artificial fertilizers, and yet they do not have enough for manure for their crops or food for their stock. The air contains unlimited supplies of nitrogen, which the farmer may have without money and without price, except the cost of cultivating plants which gather it from the air. These plants are the legumes, such as the clovers, alfalfa, vetch, beans, peas, cowpeas, and the like.

ECONOMIC APPLICATIONS.

The value of food for nourishment depends upon the actually nutritive ingredients or nutrients which it contains. Of these the most important is protein, which occurs in the lean of meat, white of egg, casein of milk, gluten of wheat, and corresponding compounds of other materials used as the food of domestic animals. Protein contains the element nitrogen. It forms blood, muscle, bone, tendon, and other tissues of the body. The other chief classes of nutrients are carbohydrates and fats. Sugar and starch are carbohydrates. The fat of meat, butter, and the oils of corn, wheat and other grains, are familiar examples of fats. Grains and grasses have large proportions of carbohydrates, and but little fats. The fats and carbohydrates of the food form the fat of the body, and are consumed in it to yield heat to keep it warm and muscular strength for work. They are thus the fuel-materials of the food.

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* Part of the work of the investigation has been conducted by the Station in connection with the U. S. Department of Labor. The larger portion, however, was done in the chemical laboratory of Wesleyan University, in connection with the Massachusetts Bureau of Statistics of Labor, the U. S. Fish Commission, and the Smithsonian Institution. The importance of comparison of our food production and consumption with those in Europe has led to the collating of the results of a considerable amount of study of these subjects by European investigators, and some of the principal results are also given in the Report.

Explanations and practical applications regarding the nutritive values of our ordinary food materials and the economy of their use were given in Bulletin No. 7 of the Station.

Food constitutes the chief item of the living expenses of the people and of our agricultural production, and one of the most important of our exports to Europe.

Wage-workers and people of moderate incomes generally in New England spend and must spend nearly half their earnings for food. The health and strength of all are intimately connected with and dependent upon their diet. Yet even the most intelligent people know less of the actual uses and values of their food for fulfilling its purposes than they do of those of almost any other of the necessities of life. In consequence there is great waste in the purchase and use of food, loss of money, and injury to health.

We make a three-fold mistake in our food economy. First, we purchase needlessly expensive kinds of food. The cheapest food is that which supplies the most nutriment for the least money. The most economical food is that which is the cheapest and at the same time the best adapted to the wants of the user. The maxim that "the best is the cheapest," does not apply to food. The best food, in the sense of that which is the finest in appearance and flavor, and which is sold at the highest price, is not generally the cheapest, nor is it always the most healthful or economical. Even among those who desire to economize, there is great pecuniary loss from the selection of materials in which the actual nutrients are really, though not apparently, dearer than need be.

Many laboring people make the grave mistake of believing that the highest-priced food materials are the best, and purchase accordingly. As a class, they consume large amounts of the dearer kinds of meats. The fact is that the cheaper cuts of meat are just as nutritious, and when properly cooked are very palatable. Many whose means are limited err seriously in their choice of food, so that they are often inadequately nourished when they might be well fed at less cost; and, what is the most painful thing of all, it is generally the very poor who practice the worst economy in the purchase as well as in the use of their food. Here as elsewhere it is true that "to him that hath shall be given, but from him that hath not shall be taken away even that which he hath."

Second, the food which we eat does not always contain the proper proportions of the different kinds of nutritive ingredients. We consume fats and carbohydrates in relative excess. People in this country eat what is set before them, asking no questions for economy's sake, provided it suits their taste. We are a generation of fat, starch, and sugar eaters. We are so because of the abundance and toothsomeness of foods containing these ingredients.

Third, in this country many people—not only the well-to-do, but those in moderate circumstances also—use a needless quantity of food; part of this excess, however, is simply thrown away, so that the injury to health, great as it may be, is doubtless much less than if all were eaten. The investigations here referred to confirm the general impression that we consume much more food than is required for our best nourishment, and that this is especially the case with people who do but little muscular work.

Allowing that the food consumption of which statistics have been collated is approximately representative of that of people in the United States generally, we are led to the conclusion that our national dietary has become one-sided, so that, although we live upon a high nutritive plane, our food might be better fitted to our needs. The chief error seems to be in the use of needless quantities of the fatter kinds of meat and sweet-meats.

The subject is an important one for wage-workers. Statistics, as well as common observation, bear emphatic testimony to the better condition of the American as compared with the European workingman, in respect to his supply of the necessaries and comforts of life. Nowhere is this superiority more striking than in the quality and quantity of the food.

The American workingman is better paid, better housed, better clothed, and better fed than the European. He has better opportunities for self-development, more to stimulate his ambition, and more hope of reward if his work is efficient. He accomplishes a great deal more. That this superiority is due to more nutritious food, as well as to greater intelligence, is hardly to be questioned.

But the better nourishment of the American wage-worker is largely due to our abundant food production. With the growth of population, and the increasing closeness of home and international competition, his own diet cannot be kept up to its present standard, nor can that of his poorer neighbor and his foreign brother be brought up to that standard without better knowledge of the laws of food economy.

To the farmer this subject is of vital interest. The agricultural production of the United States is out of balance. Our food supply for man and beast contains an excess of the materials which serve the body for fuel and are relatively deficient in the nitrogenous compounds which make blood, muscle, and bone. In other words, the farmer produces relatively too much starch, sugar, and other carbohydrates; too much fat and too little protein. The crops he grows are, taken together, deficient in protein, and the meat he makes is excessively fat. The one-sidedness of our food consumption is the natural result of the one-sidedness of our food production.

This one-sidedness of our agricultural production is easily explained. In the first place, our vegetable products are deficient in protein. Corn, our great staple, is poor in protein at best. From careless culture, insufficient manuring, or other reasons, our grasses, grains, and other crops contain much lower proportions of nitrogen than they ought to, and much less than the same ones do in Europe, where farming is more thoroughly done. In the second place, our meats, upon which we depend to supply the protein which our vegetable foods lack, are excessively fat. This excessive production of fat in meat is uneconomical in several ways. A large amount of vegetable feeding stuffs is required to make a small amount of fat, much protein is lost in the process, and the fat thus produced is sold in a food market where it comes in competition with other materials of which there is a relative overproduction.

The fat of meat, lard, butter, cotton-seed oil, sugar, and the starch which constitutes the larger part of the nutritive material of wheat and other grains and nearly the whole of that of potatoes, all do the same work in nutrition—they are the fuel of the body. The cattle grower, the pork producer, the dairyman, the sugar maker, the raiser of wheat and potatoes, and the cotton planter, are engaged in an unwitting, but none the less severe, competition with each other in supplying the food market with fuel-materials, with which it is relatively overstocked, and are all competing with petroleum.

The one-sidedness of our dietary is the result of this one-sidedness of our agricultural production. As the farmer is primarily responsible for this state of affairs, and the first loser by it, so he must be the one to take the first steps to amend it. The remedy for the evil is to grow crops with more protein. The needed increase of protein may be obtained by breeding and importing varieties of grains and grasses richer in nitrogen than those we now cultivate, and by growing more legumes, such as clovers, alfalfa, vetch, seradella, cowpeas, peas, and beans.

The value of nitrogenous feeding stuffs is not sufficiently appreciated, but the progress of exact experiment in this country and in Europe is bringing it out more and more clearly.

FORAGE CROPS.

C. S. PHELPS.

The Station has grown a variety of fodder crops during the past two years, for feeding to milch cows through the summer months. The system practiced is what is known as soiling, or the feeding of animals in the stables, during the growing season, largely or wholly on green fodders. The practice of soiling is especially advantageous near cities and towns, where the land is too valuable to be used for pasturage. The advantages claimed for the soiling system may be summed up as follows: A comparatively small amount of land is required; the food supply can be regulated; the animal does not waste its energy in searching for and obtaining its food; and, finally, the manure may be well preserved for use in growing cultivated crops.

In soiling, it is important to have a regular succession of fodders throughout the growing season. There should be no breaks in the succession, and each crop should be used as nearly as possible at the time when it is in its best shape for feeding. Fodder crops are generally considered to be in the best condition for feeding when in early bloom. If fed much before this time they will not have made full growth, and light yields will result; while if allowed to remain standing till past the flowering period, the fodder becomes relatively poorer in the protein, which is the most valuable food constituent, and is not as freely eaten nor as completely digested. According to our experience, the best results seem to be obtained when the fodder from a single planting or sowing is not fed longer than ten to twelve days. The same kind of crop may be made available for longer periods by planting or sowing small plots successively, and feeding from these as the fodder on each reaches its best stage of growth.

The forage crops grown during 1891 consisted of wheat fodder, clover and grass, oats and peas, oats and vetch, clover rowen, Hungarian grass, cowpeas, and barley and peas. These gave a succession of green fodders lasting from June 3d to November 1st.

A SERIES OF CROPS FOR SOILING.

In arranging a series of crops for soiling throughout the entire summer, it becomes important to know the best times for sowing or planting, and when the crops will best serve for feeding. The time of seeding and of feeding must vary somewhat with the climate and season, hence fixed dates cannot be given. From three years' experience and observation in the practice of soiling, we are disposed to recommend the following for central Connecticut:

Kind of Fodder.	Amount of Seed Per Acre.	Approximate Time of Seeding.	Approximate Time of Feeding.
1. Rye fodder, - - -	2½ to 3 bush.	Sept. 1.	May 10–20.
2. Wheat fodder, - - -	2½ to 3 bush.	Sept. 5–10.	May 20, June 5.
3. Clover, - - - -	20 lbs.	July 20–30.	June 5–15.
4. Grass (from grass lands), -	—	—	June 15–25.
5. Oats and peas, - - -	2 bush. each.	April 10.	June 25, July 10.
6. Oats and peas, - - -	2 bush. each.	April 20.	July 10–20.
7. Oats and peas, - - -	2 bush. each.	April 30.	July 20, Aug. 1.
8. Hungarian, - - -	1½ bush.	June 1.	Aug. 1–10.
9. Clover rowen (from 3), -	—	—	Aug. 10–20.
10. Soja beans, - - -	1 bush.	May 25.	Aug. 20, Sept. 5.
11. Cowpeas, - - -	1 bush.	June 5–10.	Sept. 5–20.
12. Rowen grass (from grass lands), - - - -	—	—	Sept. 20–30.
13. Barley and peas, - -	2 bush. each.	Aug. 5–10.	Oct. 1–30.

Owing to the high feeding value of the legumes, the large amount of valuable manure they furnish, and their natural tendency to improve rather than deplete the fertility of the soil, it has been thought best to give such crops as clover, field peas, vetch, soja beans, and cowpeas a leading place in the above series. Fodder corn may be used to advantage during the latter part of August, and most of September. While the actual yields are generally greater with corn than with soja beans or cowpeas, the feeding value of the nutrients is considerably less. The demand for fertilizers and consequent drain upon the soil is far greater with fodder corn.

The value of legumes for fodder and manure was summarized as follows in Bulletin No. 6 of the Station:

This class of plants are especially valuable because of—

(1.) Their large percentages of protein compounds which serve to form blood, muscle, bone and milk, and their consequent feeding value, which exceeds that of the grasses, corn fodder, corn stover, or straw. They may be used to supplement these fodders in place of the concentrated nitrogenous feeds, such as bran, cotton seed, linseed, and gluten meals, etc. Hay from the legumes is twice or more than twice as rich in protein as that from the grasses.

(2.) Their power of gathering large quantities of plant food from natural sources. Many, if not all, of our common legumes acquire considerable quantities of nitrogen from the air. Their roots penetrate deeply into the subsoil, and they thus obtain plant food from depths beyond the reach of plants with smaller root development.

(3.) Their manurial value. When the crop is fed, most of the nitrogen, phosphoric acid, potash, and other fertilizing ingredients go into the excrement, liquid and solid, and if preserved, make a rich manure. If the crop is plowed under, its plant food, including that acquired from the air and gathered from the subsoil, becomes available for succeeding crops. The large amounts of plant food left in roots and stubble after the removal of the crop, furnish a cheap and valuable store of plant food for following crops.

While the clovers will doubtless prove in the future, as they have in the past, the most valuable of the legumes for general purposes in Connecticut, the cowpea, soja bean, and vetches are valuable for forage, silage, or hay, and the experiments and observations at the Station and elsewhere indicate that they are worthy of careful trial.

NITROGEN OF THE AIR AS PLANT FOOD.

CHAS. D. WOODS.

The experiments reported upon include only a small part of the work of the Station along this line during the past three years. They are similar to those made earlier, and published in Bulletin No. 5 and in the Second Annual Report of the Station. The plants were grown, not in soil, but in sea sand which had been washed and burned to remove all traces of nitrogen compounds. They were watered with nutritive solutions. These consisted of water which had been freed from nitrogen compounds and in which were dissolved small quantities of chemicals containing lime, potash, phosphoric acid, and the other mineral ingredients of plant food. In some cases small quantities of nitrogen compounds, nitrate of potash or lime, were added. The plants were in many cases larger than those grown in rich garden soil. The amount of nitrogen supplied at the outset in the seed or in seed and nutritive solution, and the amounts in the plant or plant and nutritive solution at the end, were determined by analysis. The excess at the end over the amount supplied must have come from the air. This gain was frequently very large. It was especially so where no nitrogen was supplied in the solution and the plants were nevertheless thrifty, as was the case in a number of instances. All of the nitrogen of these plants, except that which came from the seed, was obtained from the air.

The acquisition of large quantities of nitrogen from the air by plants was demonstrated in experiments with peas, by Prof. Atwater, in the years 1881–2. The results were confirmed later by other investigators, especially Hellriegel in Germany, who was the first to show that in some way the bacteria or other microbes in the soil and the tubercles or enlargements which appear on the roots of leguminous plants are connected with this acquisition of nitrogen. The results of fifty experiments by the Station in 1891, added to those of some two hundred in previous years, demonstrated that not only the peas, vetch, and alfalfa, but also cowpeas, beans, and scarlet clover, have made use of the nitrogen of the air. European experiments have shown that other species of legumes do the same, and it now seems probable that all our common legumes have this faculty.

SPECIAL NITROGEN EXPERIMENT ON GRASS.

CHAS. D. WOODS AND C. S. PHELPS.

Most farmers in Connecticut depend almost entirely upon the use of stable manures in the production of hay, preferring to use commercial fertilizers, if at all, on the hoed crops. Few, if any, of our ordinary farm crops make quicker and more profitable response to commercial fertilizers than grass. It is frequently the case in growing farm crops that the best results are obtained by the use of stable manures together with some commercial form of plant-food that serves to meet the special requirements of the crop or soil. Grass responds readily to soluble nitrogen compounds. A medium-heavy application of stable manure in the fall or winter, followed by a light application of nitrate of soda or sulphate of ammonia about the first of May, is often found to give the most profitable results on grass.

The object of this experiment is to observe the effects of nitrogenous fertilizers upon grass as shown by the yield per acre, the financial results, and the chemical composition of the hay. It is similar to the special nitrogen experiments upon corn that have been conducted by the Station in previous years. The field had been in grass for several years, and the soil was considerably reduced in fertility. Mineral fertilizers (phosphoric acid in dissolved bone-black and potash in muriate) were applied to all the plots except two, which were left unmanured. To all the manured plots except two, nitrogen in the form of nitrate of soda or sulphate of ammonia, was applied, at the rate of 25, 50, and 75 pounds per acre. The experiment has been carried through two years, and is to be continued.

The addition of mineral fertilizers increased the yield of clover very markedly in 1890, and somewhat so in 1891, but did not seem to increase very decidedly the yield of grass. The yield of hay in 1890 increased with the quantity of nitrogen supplied, whether it was applied in the form of nitrate of soda or sulphate of ammonia. In 1891, the largest yield was obtained from the plot on which nitrate of soda was applied at the rate of 50 pounds per acre. The mineral fertilizers in both years, when used alone, were applied at a financial loss. The best financial returns, a gain of $5 per acre, were obtained in both seasons from the use per acre of 320 pounds of nitrate of soda (50 pounds of nitrogen) in addition to the mixed minerals. The drouth in the early part of June made the season of 1891 an unfavorable one for fertilizer experiments on grasses.

The application of nitrogenous fertilizers increased the percentages of protein (nitrogen multiplied by 6.25) in the grasses, and somewhat in proportion to the amounts applied. This is in accord with observations made by the Station upon the relation of the protein in corn and stover to the nitrogen applied in the fertilizers. Since protein, which makes blood, bone, muscle, and milk, is a most important ingredient of food, and is apt to be deficient in our feeding stuffs, this increase of protein from the use of nitrogen is an important matter.

While clover and the other legumes may be called "nitrogen collectors," the grasses, such as timothy, redtop, etc., must be classed with the "nitrogen consumers." Fertilizers containing potash or phosphoric acid without available nitrogen, are usually much less effective for grass than if they have nitrogen in addition. It would seem desirable that fertilizers for grass lands should, therefore, contain considerable quantities of nitrogen in a readily available form. Their use has the two-fold advantage of increasing the total yield and the feeding value of the crop.

FIELD EXPERIMENTS WITH FERTILIZERS BY FARMERS.

C. S. PHELPS.

The Station has continued its coöperative field experiments through a fourth year, the plan being essentially the same as that adopted in the spring of 1888. The experiments have been of three classes: "Soil Test," "Special Nitrogen Experiments," and "Special Corn Experiments."

The object of the experiments may be stated briefly as follows:

(1.) To work directly upon farm lands in different parts of the State, and to aid the owners in learning the deficiencies of their soils and the requirements of their crops.

(2.) To help farmers in becoming familiar with the forms and action of fertilizing materials containing phosphoric acid, potash, and nitrogen, and to better understand their profitable use.

(3.) To encourage a spirit of investigation, and thus to gradually develop a number of farm experimenters, whose work will be useful not only to themselves, but in a larger degree to their communities and to the agriculture of the State.

SOIL TEST EXPERIMENTS.

The plan of experiments for soil tests consisted in applying, on parallel plots of land, fertilizers containing nitrogen, phosphoric acid, and potash, singly, two by two, and all three together. The fertilizing materials were in all cases supplied by the Station, in standard commercial forms, such as nitrate of soda, dissolved bone-black, and muriate of potash. Dissolved bone-black was applied at the rate of 320 lbs., supplying about 50 lbs. of phosphoric acid, and muriate of potash at the rate of 160 lbs. with 80 lbs. of "actual potash," and nitrate of soda at the rate of 160 lbs. with 25 lbs. of nitrogen per acre.

Experiments of this class have been carried on by R. S. Hinman, Oxford; H. W. Sadd & Son, Wapping; F. L. Ensworth, Canterbury; Jerome Warren, Putnam; and at the Station.

The experiments of 1891 as well as those of former years reveal great differences in soils as regards their natural stores of available plant food. Soil tests covering a period of three years have shown fertilizers containing potash or nitrogen or both to have the leading effect on light sandy and loam soils, while those supplying phosphoric acid have produced the most marked effect on clay soils.

SPECIAL NITROGEN EXPERIMENTS.

The object of this class of experiments is to study the effect of larger and smaller quantities of nitrogen on different crops, while the amounts of mineral fertilizers, dissolved bone-black, and muriate of potash, remain constant. There are two prominent points to be considered, the effect of the fertilizer on the yield, and the effect on the composition and feeding value.

Experiments show that plants differ widely in the readiness with which they respond to applications of nitrogen, and in their peculiar powers of gathering nitrogen from natural sources. Clover, vetches, alfalfa, and other legumes seem to demand but little nitrogen, while grass, oats, and wheat require a great deal, and generally increase in yield with increased applications of this element.

Experiments of this kind have been conducted during the past year at the Station, on grass, and by M. H. Dean, Falls Village, on potatoes. In nearly all of the experiments on corn made during the past three years large quantities of nitrogen have caused but little increase in yield over the smaller quantities; while with grass, oats and potatoes the yield has increased somewhat in proportion to the amounts of nitrogen used. In general the use of large amounts of nitrogen in readily soluble forms has proved unprofitable.

SPECIAL CORN EXPERIMENTS.

This class of experiments was planned to study the best proportions of phosphoric acid and potash for corn on soils whose peculiarities had been studied by soil tests. The profit or loss from the use of the mixtures was also considered.

The most profitable mixture for use in growing any particular crop depends not only on the adaptability of the fertilizer to the soil and crop, but very largely on the market price of the materials used and on the business tact of the farmer in purchasing.

These experiments were conducted upon the farms of K. B. Loomis, So. Manchester; J. H. Tucker, Lebanon; and Clifton Peck, Franklin.

They are new and have not been continued long enough to give many practical results. They already suffice, however, to enforce the economy of adapting fertilizers to the soil. In one experiment in 1891 the best yield was obtained by the use of a home-mixed fertilizer prepared at a cost of several dollars per ton less than the better special corn mixtures in the market.

GENERAL CONCLUSIONS.

The results of this year's experiments confirm those of former years, and seem to warrant the following general deductions:

(1) Soils cannot be cultivated with the greatest profit without a knowledge of their deficiencies in plant food.

(2) The best practical means of learning the deficiencies of soils, and the most profitable manures for our various farm crops when grown on different soils, seems to be by tests with fertilizers.

(3) An insight into the subject of the feeding powers of plants is only secondary in importance to a knowledge of the soil. A large number of experiments indicate that the regu-

lating ingredient may vary with different crops on the same soil, a circumstance due, at least in part, to differences in the feeding powers of plants.

(4) Soils of the same general character usually show the same deficiencies. The experiments of 1891, as well as those of the past three years, indicate that heavy clay soils in Connecticut are generally lacking in phosphoric acid, while light sandy and loamy soils, having porous subsoils, are most apt to be deficient in potash.

(5) Fertilizers should be so compounded as to meet the deficiencies of the soil, and, at the same time, supply the special needs of the crop. Without a knowledge of the soil, we may be furnishing those ingredients in which the soil abounds, and be withholding just what it lacks. This has been well illustrated in experiments in the Housatonic Valley, made during the past three years, where potash is so efficient and phosphates do so little good.

(6) The relation of plants to the nitrogen supply is one of the most important and difficult problems in the use of fertilizing materials. Experiments made in this State, covering a period of eight years, indicate that soluble nitrogenous fertilizers should be sparingly used, on nearly all soils, for corn; while potatoes, oats, and grass require much larger amounts. On the other hand, the legumes, such as peas, beans, clover, alfalfa, vetches, and lupines are often profitably grown without nitrogen, other than that obtained from the air and that stored in the soil.

(7) The wide differences found in soils, and in the demands of different crops for plant food, afford a strong argument in favor of home-mixed fertilizers. Their economy has been well illustrated by farmers in this State. The special needs of different soils cannot be considered by the manufacturer who prepares his goods for general use. The farmer can dispense with the services of middle-men, and prepare such mixtures as will supply the lack found in his soil, and at the same time meet the requirements of particular crops.

PELTON & KING, PRINTERS,
MIDDLETOWN, CONN.

STORRS SCHOOL

Agricultural Experiment Station,

STORRS, CONN.

BULLETIN No. 9.—NOVEMBER, 1892.

Soiling and Soiling Crops.

Feeding Experiments with Soiling Crops.

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* The Director was absent during most of the time in which the experiments here reported were being made, and is now in Europe. The Vice-Director and the Agriculturist are therefore responsible for the details of the work and for this Bulletin.

SOILING AND SOILING CROPS.

BY C. S. PHELPS.

The use of fodder crops for soiling and for supplementing pasture feed is becoming more common each year, in all of the better dairy regions of the country. Two systems are practiced: Soiling, by which is meant the feeding of animals in the stables mostly, or wholly, on green fodders. The animals are generally given "the run" of a small yard several hours in the day for exercise. The other and more common system is what is known as partial stall feeding, or as partial soiling. In this case the animals are in pasture most of the day, but are given green fodders in the stalls either at night or in the morning, or both. Owing to the abundance of cheap pasture lands, the first system has not been largely followed in this country.

The advantages of soiling may be briefly stated as follows: A comparatively small area will feed a large number of animals; only a small amount of fencing is necessary; the food supply can be closely regulated and kept quite uniform throughout the season; nearly all of the food is available for the formation of products, as there is no waste of energy in searching for food, and the manure may be all saved and used in growing cultivated crops. This method of feeding is fast claiming the attention of milk producers and other dairymen living on small, fertile farms, where land is too valuable to be used for pastures, and where the animal products have a ready sale in near markets. Authorities claim that one acre in soiling will equal three acres in good pasture. During the past year the Station has, with the addition of a very light grain and straw feed, maintained from June 1st to November 1st, four cows on a little less than two and one-half acres.

Partial stall feeding is a substitute for soiling, and naturally precedes it in the growth and development of a country. The amount of feed available from pastures is very irregular. Early in the season there is usually an abundance of feed of the best quality, but, later, droughts and early frosts are apt to reduce both the quantity and quality. Unless some supplementary feed is given, the milk flow is rapidly diminished and the animals become thin in flesh. Even where lands are cheap, it seems probable that small, fertile pastures, supplemented by stall feeding, are better than large pastures where feed is scant and the animals waste much energy in gathering the necessary food.

In all cases green fodders should be fed in the mangers, as the practice of feeding in the open yard or pasture is very wasteful. If green fodders are to be used throughout the whole of the growing season, a complete succession is the first important consideration. There should be no breaks in the succession, and each crop should be used, as nearly as possible, at the time when it contains the largest amount of valuable food constituents. Fodder crops are generally considered to be in the best condition for feeding when in early bloom. If fed before this time, they will not have made full growth, and light yields will result; while if allowed to remain standing till past the flowering period, the fodder becomes woody, and is not as freely eaten nor as completely digested. Usually the best results are obtained when the fodder from a single planting or sowing is fed not longer than ten to twelve days. The same kind of crop may be made available for longer periods by planting or sowing successively small areas, and feeding as the fodder on each reaches its best stage of growth.

SOILING CROPS GROWN.

Two points have been especially kept in mind in deciding what crops to plant: the time required to grow the crop, and the quality or feeding value when grown. Rapid growing crops are to be preferred, and whenever practicable it is well to grow two different crops per year on the same area of land. Crops rich in nitrogen, (protein,) have been chosen whenever possible, the legumes entering largely into the list.

The following is a general summary of four years' experience in the use of soiling crops by this Station. Some of the results of feeding experiments with these crops will be found farther on in this Bulletin. The different fodder crops are discussed in the order of their use through the season.

Wheat Fodder.—With the possible exception of rye, this is the first crop available for summer feeding. To obtain heavy yields the wheat should be sown early in September on well manured land, at the rate of two and one-half bushels per acre. Nitrate of soda applied in April at the rate of 160 pounds per acre, greatly improved the crop on the station land. The Clawson variety has been grown for three years, the yield in 1892 being at the rate of 10.5 tons per acre. The crop was fed this season (1892) from May 24 to June 15. Wheat seems to make a better crop for green feeding than rye. It can be fed for a longer time and contains a much larger proportion of leaf growth. Rye rapidly becomes hard and woody after reaching the best feeding stage, and the stems are apt to be rejected by stock.

Clover.—A mixture of about equal parts of clover and mixed grasses has been fed for a short period following the wheat. Clover is one of the richest nitrogenous fodders, and can be fed for about ten days near the middle of June, and a second crop is generally available about August 1st. Clover can usually be obtained from the grass fields at this time or it may be grown in rotation with some crop that is fed off early in the summer. If sown about July 20th, a good growth will be obtained before winter, and the plants, being firmly rooted, are not liable to be thrown out by the freezing and thawing of the ground.

Oats and Peas.—This seems to be the best forage crop for midsummer feeding that we have tested. The Canada variety of peas has been sown with common western oats at the rate of two bushels of each per acre. The best results have been obtained by sowing small areas one week to ten days apart, beginning as early in the spring as possible. By following this plan no portion of the fodder becomes old and woody before it can be used. Peas are a rich nitrogenous fodder, while the oats are especially valuable to keep the peas from lodging. The crop furnished good feed from about June 25th to July 20th. The yield in 1891 was 14 tons, and in 1892, 11 tons per acre. The crop is well worthy of trial by farmers either for feeding green or for making into hay.

Oats and Vetch.—A mixed fodder of oats and vetch makes a good substitute for a part of the oats and peas. Vetch is a lighter plant and not as liable to lodge as peas. A Scotch variety, a larger and more vigorous grower than the English variety, was grown in 1891. The seeding was at the rate of one and one-half bushels per acre with oats at the same rate, the yield being 12 tons per acre. This season a common imported variety was sown, which gave a poor crop. Vetch is to be preferred to peas if the crop is grown for hay, on account of the ease in drying the vetch while the peas require much curing. The chief objection to the substitution of vetch for peas is the cost of the seed ($3 per bushel). If the seed could be imported at a moderate cost, or if it can be profitably grown in this country, we would recommend vetch as a valuable fodder plant.

Hungarian Grass.—If sown about June 1st, Hungarian will make a good fodder crop for use immediately after oats and peas (about Aug. 1st). This grass makes a rapid growth and needs to be liberally supplied with some quick acting fertilizer. It may also be grown to advantage as a hay crop. While Hungarian cannot be classed with the more nitrogenous fodders, it is available for soiling at a time when most other crops cannot be used to good advantage.

Scarlet Clover.—This is an annual clover which has been little grown in Connecticut. In New Jersey and Delaware it is receiving much attention. In our climate it will produce fair crops if sown as early in the spring as the ground can be thoroughly tilled. It makes a larger proportion of leaf growth than common clover and continues to grow after much of it has blossomed and hence does not become woody as quickly as common clover. Ten pounds of seed per acre were sown April 19th, 1892, but owing to drouth early in the season, the growth was slow and the yield light, being 6 tons per acre. We believe the plant worthy of careful trial as a soiling crop.

Soy Bean.—This plant makes a tall, slender growth and is not as succulent and leafy as the cow pea. It should be sown about May 20th, and from our experience appears to need a fertile soil for the best results. The plants have made a slow growth, and each season the foliage has been of a pale yellow color. The yield in 1890 was 9 tons, and in 1892, 6.4 tons per acre. The fodder has been well eaten by milch cows but the yields have been lighter than for cow peas. Both of these crops are ready for feeding at about the same time, and from our experience the cow pea is to be preferred.

Cow Peas.—Success with this fodder plant, in our climate, depends largely upon the variety and the soil. The Clay variety is the best for fodder. With a warm, light loam soil we have grown good crops for four years, only one of which was injured by frost. The fodder can be used for soiling from about August

25th till September 20th, and while the yield is not so large as with fodder corn, the quality of the feed is much better, and good crops can be grown without the use of the more expensive nitrogenous fertilizers. The Clay variety yielded at the rate of 11 tons in 1890 and in 1892, 11.4 tons per acre, while in 1891 a much poorer variety for fodder gave 8 tons per acre. This season the crop was sown June 13th, after wheat fodder, and furnished good feed from August 25th till October 3d. Seed may be obtained of T. W. Wood, Nos. 8–10 South 14th street, Richmond, Virginia, and should be ordered not later than February. Owing to the early season in the south, the seed becomes scarce long before time for planting in this latitude.

From our experience we feel warranted in recommending the following treatment for the crop: Select a warm, deep loam soil with an open subsoil. If the soil is moderately fertile, mineral fertilizers only need be used. On the Station land, 600 to 800 pounds per acre of a mixture consisting of two-thirds dissolved bone-black and one-third muriate of potash has given good results. On some poor soils a little nitrogen may be advantageously added. Sow from June 1st to 10th in drills two and one-half feet apart, at the rate of one bushel per acre. Cultivate frequently during the first part of the summer, or until the plants are ten to twelve inches high. The crop generally makes a slow growth when small, but a warm soil and frequent cultivation hasten the growth early in the season. Feed green or preserve in the silo before danger of damaging frosts. The stems are too coarse, and the plant generally too succulent, to be easily made into hay.

Barley and Peas.—This fodder crop has been sown for the past two years on the same area from which oats and peas were fed during July of the same season. The time of sowing has been the first week in August, two bushels of Canada peas and two of barley being used per acre. The crop will furnish feed throughout the entire month of October. It is not injured by frost and is ready for use at a time when pasture feed is poor and most forage crops are not available owing to frosts. The pea seed should be covered by shallow plowing, or deep harrowing by use of a disc harrow, while the barley should be lightly covered.

COMPARATIVE VALUE OF LEGUMES.

The legumes, such as clover, peas, vetch, etc., have a double value, since they are especially rich in protein and do not draw heavily on the fertilizing ingredients of the soil. Being nitrogen collectors, they obtain large quantities of this element from the air. The leaves and stems furnish this nitrogen to the animals, while the roots and stubble add considerable fertility to the soil.

The following tabulation will show the value of some of the more nitrogenous forage crops when compared with fodder corn. From the yield and analyses of the fodders there has been calculated the total amount of food constituents obtained per acre (Field A and Field B).

Valuable Constituents Per Acre.

	Total Crop.	Protein.	Fat.	Nit.-free Ext'ct.	Fiber.
Field A, 1890.	Tons.	Lbs.	Lbs.	Lbs.	Lbs.
Ensilage corn,	22.0	682	242	4546	2380
Field A, 1891.					
Oats and peas, Oats and vetch, } Equal areas of each,	10.8	605	144	2036	1200
Barley and peas,	4.9	356	67	714	500
Total, two crops,	15.7	961	211	2750	1700
Field B, 1892.					
Wheat fodder.	10.6	406	200	2692	1430
Cow peas,	11.4	570	91	935	730
Total, two crops,	22.0	976	291	3627	2160

From the table it will be seen that on Field B the yield was the same and the feeding value per acre considerably greater from the two crops of wheat and peas than from a single crop of ensilage corn. It is of interest also to note that while the yield on Field A was considerably less in 1891 than in 1890, the total amount of protein was greater by more than one-third. This fact indicates that while the yield per acre of some of the legumes may be relatively small, their feeding value is relatively high. This feature of plants of this class, coupled with the fact that they do not draw heavily upon the fertility of the soil, points to an important place for them in our system of farming.

A SERIES OF CROPS FOR SOILING.

In arranging a series of crops for soiling throughout the entire summer, it becomes important to know the best times for sowing or planting, and when the crops will best serve for feeding. The time of seeding and of feeding must vary somewhat with the climate and season, hence fixed dates cannot be given. From four years' experience and observation in the practice of soiling, we would recommend the following for central Connecticut:

Kind of Fodder.	Amount of Seed per Acre.	Approximate Time of Seeding.	Approximate Time of Feeding.
1. Rye fodder, - - -	2½ to 3 bush.	Sept. 1.	May 10–20.
2. Wheat fodder, - -	2½ to 3 bush.	Sept. 5–10.	May 20–June 5.
3. Clover, - - -	20 lbs.	July 20–30.	June 5–15.
4. Grass (from grass lands),			June 15–25.
5. Oats and peas, - -	2 bush. each.	April 10.	June 25-July 10.
6. Oats and peas, - -	2 bush. each.	April 20.	July 10–20.
7. Oats and peas, - -	2 bush. each.	April 30.	July 20–Aug. 1.
8. Clover rowen (from 3), -			Aug. 1–10.
9. Hungarian, - - -	1½ bush.	June 10.	Aug. 10–20.
10. Cow peas, - - -	1 bush.	June 5–10.	Sept. 5–20.
11. Rowen (from grass lands)			Sept. 20–30.
12. Barley and peas, - -	2 bush. each.	Aug. 5–10.	Oct. 1–30.

FEEDING EXPERIMENTS WITH MILCH COWS ON SOILING CROPS.

BY C. S. PHELPS.

During the summers of 1891 and 1892 the station has carried on a series of feeding tests with the various fodder crops described in the first part of this Bulletin. The soiling system was followed. The animals were fed in the stables, but had "the run" of a small yard several hours each day. The green fodders were hauled, as a rule, every second day, and a two days' supply weighed at once and left in baskets or separate piles, till needed. During all of the tests there was fed a standard grain ration, mixed, in most cases, with cut hay or oat straw. The object of the experiments was to study the value of various green fodders for milk and butter production, and the effect of the rations on the composition of the milk, with especial reference to the quantity of fat produced. In 1891 the fats only were determined and in 1892 both the fats and solids. The total amount of butter fat was estimated by multiplying the weight of milk from each milking by its percentage of fat and adding the results for the four or seven days which made up the test.

THE EXPERIMENTS.

During the seasons of 1891 and 1892 green fodder crops were fed from about June 1st till November 1st and the feeding tests were carried on in 1891 from June 8th till September 22d, and in 1892 from May 29th till August 15th. The amount of green fodder fed varied from 50 to 75 pounds according to the moisture in the crop. The amount of grain fed remained constant for both seasons and consisted of three pounds of corn meal, and one pound of new process linseed meal per day. This was fed with a small quantity of cut hay or oat straw.

Four animals were used each season and in 1891 consisted of the following: Cows No. 2 and 5 were grade Jerseys about seven years old and had calved during the first week of November, 1890. Their weight at the beginning of the tests were 770 and 830 pounds respectively. Cow No. 1 was a high grade Jersey, six or seven years old, that had calved February 11th, 1891, and weighed 740 pounds, and cow No. 3, a Guernsey and high grade Jersey cross, that had calved February 5th, 1891 and weighed 950 pounds. The same animals were used in the experiments of 1892, with the exception that the grade Jersey No. 5, was replaced by another, designated as No. 4. This cow calved about October 1st, 1891, and weighed June 18th, 1892, 850 pounds. Cow No. 2 calved December 1891, cow No. 3, February 12th, and cow No. 1, April 3d, 1892. It will be observed that two of the cows were well along in their periods of lactation, having given milk from six to eight months when the tests began, while the other two were two to four months past calving.

The tests in 1891 were each four days in length and in 1892 seven days, and whenever practicable two or more tests were made from the same fodder. In all cases three or four days were allowed to accustom the animals to a new feed, before the tests were begun.

COMPOSITION OF THE FODDERS.

The table which follows gives the composition of the green fodders used. Each fodder was sampled during the time of feeding, and the results of the analyses are given calculated to water content at the time of sampling.

Analyses of Green Fodders grown by Station.

Year.	KIND OF CROP.	Wat'r	Pro-tein.	Fat.	Nit.-free Ext.	Fiber	Ash	Pot'nl En'gy.
		%	%	%	%	%	%	Calor's per lb.
1891	Wheat, - - - - -	69.9	3.7	1.0	14.8	9.0	1.6	550
1892	Wheat, - - - - -	76.2	2.6	.9	12.5	6.3	1.5	440
1892	Wheat, - - - - -	74.2	2.2	1.0	12.9	8.1	1.6	475
1891	Oats and peas, - - -	82.9	3.0	.6	7.4	4.7	1.4	305
1892	Oats and peas, - - -	83.8	3.5	.7	6.2	4.3	1.5	290
1892	Oats and peas, - - -	84.6	3.5	.8	6.0	3.7	1.4	280
1891	Oats and vetch, - - -	75.4	3.6	.7	11.8	6.5	2.0	440
1891	Red clover rowen, - -	70.2	6.0	1.4	13.6	6.7	2.1	550
1891	Timothy and clover rowen,-	81.3	3.7	.9	8.0	4.3	1.8	335
1892	Red clover rowen, - -	75.4	4.7	.8	11.1	6.0	2.0	440
1892	Scarlet clover, - - -	79.5	3.1	.8	8.5	6.3	1.8	365
1891	Hungarian, - - - -	72.8	2.5	.8	14.1	7.7	2.1	485
1891	Hungarian, - - - -	72.7	3.3	.8	12.6	7.9	2.7	475
1892	Hungarian, - - - -	71.5	3.1	.9	13.3	9.1	2.1	515
1892	Hnngarian, - - - -	72.4	1.9	.9	14.0	8.6	2.2	500
1891	Cow peas, - - - - -	83.6	3.2	.4	7.7	3.3	1.8	280
1892	Cow peas, - - - - -	88.3	2.5	.4	4.1	3.2	1.5	200
1891	Barley and peas, - -	84.1	3.0	.6	6.1	4.3	1.9	275

THE RATIONS FED.

During most of the trials 60 pounds of green fodder was used. The grain remained constant, and the dry hay or oat straw was lessened whenever the animals were inclined to refuse it. Owing to the small number of digestion experiments on green fodders from which data might be had, it was thought best to assume uniform digestion coefficients for all of the fodders. These are essentially the same as Armsby gives for red clover beginning to blossom, and were as follows: For protein 75 per cent. digestible; fat, 60 per cent.; nitrogen free extract, 75 per cent.; and fiber 50 per cent.

From the table of rations given on the following page it will be seen that the amount of total digestible nutrients in the fodders varied widely. It will also be noticed that the proportions of protein were largest whenever clover, vetch, peas or other plants of this class entered largely into the rations. By comparison with the standard ration given at the bottom of the table, it will be seen that rations VII. and IX., which gave the most striking results in the feeding tests, were much narrower, that is, contained a much larger proportion of protein than that called for by the German standard of Wolff. Recent German experiments on milch cows have shown that better results are obtained from the use of considerably larger quantities of protein than the German standards have hitherto called for.

Amounts of Digestible Nutrients and Calories of Potential Energy in the Rations.

No. of Ration.	KIND OF FEED.	Weight as Fed.	Total Dry Matter.	DIGESTIBLE NUTRIENTS.			Potential Energy.	Nutritive Ratio.
				Protein.	Fat.	Carbo-hydrates.		
1891.		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	
I.	Wheat fodder, - -	42	12.64	1.16	.26	6.53		
	Hay, - - - - -	5	4.29	.21	.07	2.07		
	Corn meal, - - -	3	2.60	.22	.10	1.96		
	New Process linseed meal,	1	.90	.29	.03	.37		
	Total, - - -		20.43	1.88	.46	10.93	25770	1:5.9
II.	Timothy and clover, -	50	14.45	1.31	.29	7.50		
	Grass and hay same as I.,		7.79	.72	.20	4.40		
	Total, - - -		22.24	2.03	.49	11.90	27980	1:6.5
III.	Oats and peas, - -	50	8.53	1.11	.19	3.94		
	Grain same as I., hay 3 lbs.		6.07	.63	.17	3.57		
	Total, - - -		14.60	1.74	.36	7.51	18720	1:4.8
IV.	Oats and peas, - -	60	10.23	1.33	.23	4.73		
	Grain & hay same as III.,		6.07	.63	.17	3.57		
	Total, - - -		16.30	1.96	.40	8.30	20770	1:4.7
V.	Oats and vetch, - -	60	14.75	1.63	.26	6.71		
	Grain & hay same as III.,		6.07	.63	.17	3.57		
	Total, - - -		20.82	2.26	.43	10.28	25140	1:5.0
VI.	Hungarian, - - -	60	16.33	1.15	.28	8.68		
	Grain & hay same as III.,		6.07	.63	.17	3.57		
	Total, - -		22.40	1.78	.45	12.25	27990	1:7.5
VII.	Clover rowen, - -	60	17.89	2.69	.51	8.13		
	Hay, - - - - -	2	1.71	.08	.03	.83		
	Grain same as I., - -		3.50	.51	.13	2.33		
	Total, - - - -		23.10	3.28	.67	11.29	29930	1:4.0
VIII.	Hungarian, - - -	60	16.36	1.49	.28	8.05		
	Grain & hay same as VII.,		5.21	.59	.16	3.16		
	Total, - - -		21.57	2.08	.44	11.21	26580	1:5.9
IX.	Clover and timothy rowen,	60	11.20	1.68	.31	4.91		
	Grain & hay same as VII.,		5.21	.59	.16	3.16		
	Total, - - -		16.41	2.27	.47	8.07	21220	1:4.1
X.	Cow peas, - - -	60	10.69	1.25	.17	5.05		
	Grain & hay same as VII.,		5.21	.59	.16	3.16		
	Total, - - -		15.90	1.84	.33	8.21	20090	1:4.9
1892.								
XI.	Wheat fodder, - -	60	14.87	1.08	.34	7.59		
	Oat straw, - - -	2	1.81	.03	.01	.81		
	Corn meal, - - -	3	2.51	.22	.08	1.89		
	New Process linseed meal,	1	.88	.30	.03	.34		
	Total, - - -		20.07	1.63	.46	10.63	24750	1:7.2
XII.	Oats and peas, - -	70	11.06	1.85	.32	4.60		
	Grain and straw same as I.,		5.20	.55	.12	3.04		
	Total, - - -		16.26	2.40	.44	7.64	20530	1:3.6
XIII.	Hungarian grass, - -	70	19.95	1.62	.38	10.15		
	Grain same as I., - -		3.39	.52	.11	2.23		
	Total, - - -		23.34	2.14	.49	12.38	29080	1:6.4
XIV.	Clover (mixed), - -	60	12.90	1.57	.27	6.00		
	Grain same as I., - -		3.39	.52	.11	2.23		
	Total, - - -		16.29	2.09	.38	8.23	20600	1:4.4
XV.	Hungarian grass, - -	70	19.37	1.00	.37	10.38		
	Grain same as I., - -		3.39	.52	.11	2.23		
	Total, - - -		22.76	1.52	.48	12.61	28310	1:9.1
	German standard for 800 lb. cow, - -		19.20	2.00	.32	10.00	23670	1:5.4

THE RESULTS OF THE EXPERIMENTS.

The table which follows gives the pounds of milk, the pounds of fat and the average percentage of fat for the four cows in periods of four days for 1891, and seven days for 1892. The total solids produced in seven days and the average percentage of solids is also given in the results for 1892. It must be borne in mind that as cows advance in their periods of lactation there is a natural shrinkage in the milk flow, and a slow, but more or less gradual rise in the percentage of fat and solids contained in the milk. For this reason only tests that are quite near each other in point of time, are comparable.

Average Results of Experiments with Four Cows.

No. of Period.	No. of Ration.		Milk.	FAT.		SOLIDS.		Butter by Churning.	Milk required to make 1 lb. Butter.
			Lbs.	Lbs.	%	Lbs.	%	Lbs.	Lbs.
		Periods of 4 days each, 1891.							
1	I.	Wheat, - - - - -	327	16.1	5.0	—	—	14.4	23
2	II.	Timothy and clover, -	284	14.4	5.1	—	—	14.0	20
3	II.	Timothy and clover, -	267	13.6	5.1	—	—	13.7	19
4	III.	Oats and peas, - -	269	13.3	4.9	—	—	13.9	19
5	IV.	Oats and.peas, - -	270	13.4	5.0	—	—	14.2	19
6	IV.	Oats and peas, - -	266	12.9	4.9	—	—	13.3	20
7	V.	Oats and vetch, - -	248	11.9	4.8	—	—	12.5	20
8	V.	Oats and vetch, - -	237	11.7	4.9	—	—	12.5	19
9	VI.	Hungarian, - - -	249	12.4	5.0	—	—	13.1	19
10	VII.	Clover rowen, - -	283	15.6	5.5	—	—	16,4	17
11	VII.	Clover rowen, - -	289	14.9	5.2	—	—	16.1	18
12	VII.	Clover rowen, - -	269	13.7	5.1	—	—	14.4	19
13	VIII.	Hungarian, - - -	249	12.6	5.1	—	—	12.7	20
14	IX.	Clover and timothy, -	230	13.4	5.8	—	—	13.3	17
15	IX.	Clover and timothy, -	236	12.7	5.4	—	—	13.1	18
16	X.	Cow peas, - - -	205	11.0	5.4	—	—	10.9	19
17	X.	Cow peas, - - -	214	11.4	5.3	—	—	11.0	19
18	X.	Cow peas, - - -	212	11.3	5.3	—	—	11.8	18
19		*Periods of 7 days each, 1892,*							
20	XI.	Wheat, - - - - -	553	24.7	4.5	74.3	13.5	26.4	21
21	XI.	Wheat, - - - - -	490	22.6	4.7	68.6	14.1	24.8	20
22	XII.	Oats and peas, - -	391	18,4	4.8	54.0	14.0	18.1	22
23	XII.	Oats and peas, - -	379	17.5	4.7	51.0	13.6	18.6	21
24	XII.	Oats and peas. - -	371	17.2	4.8	49.6	13.8	19.8	19
25.	XIII.	Hungarian grass, - -	368	18.1	4.9	50.3	13.8	19.8	19
26	XIV.	Clover, - - - -	363	18.5	5.2	51.2	14.1	20.5	18
	XV.	Hungarian grass, - -	342	16.5	4.9	47.7	13.9	18.9	18

The tests of especial interest are those with clover and with Hungarian grass. These tests were quite near each other, and as the effects of the feed were most marked during these periods, the results for each cow are here given.

Pounds of Milk, and Average Percentage of Fat in periods of four days during the Clover and Hungarian tests.

No. of Period	Kind of Feed.	Cow No. 1.		Cow No. 2.		Cow No. 3.		Cow No. 5.	
		Milk	Fat	Milk	Fat	Milk	Fat	Milk	Fat
		Lbs.	%	Lbs.	%	Lbs.	%	Lbs.	%
9	Hungarian, - -	70.5	4.7	73.6	4.9	49.8	5.8	55.1	4.7
10	Clover rowen, - -	79.8	5.3	84.6	5.3	54.2	6.6	64.1	5.1
11	Clover rowen, - -	77.4	4.9	89.5	4.9	55.5	6.1	66.8	4.9
12	Clover rowen, - -	72.2	5.1	82 8	4.7	52.8	5.9	61.4	4.9
13	Hungarian, - -	64.9	4.9	79.1	4.5	49.7	6.0	55.3	5.1
14	Clover and tim. rowen,	62.6	5.6	76.7	5.5	44.1	6.6	46.6	6.0
15	Clover and tim. rowen,	65.3	5.2	81.2	5.0	43.7	6.2	45.8	5.5

In the tests with clover it will be noticed that there was, in the case of each cow, considerable increase in the milk flow, in the total fat, and in the percentage of fat in the milk over that of the Hungarian test just preceding. This increase was most marked during the first clover test.

The Hungarian tests following the three clover tests, showed in the case of each cow, a falling off in the total fat, and, in the case of cows 1 and 3, a slight decrease in the percentage of fat. During the tests with clover and timothy rowen (Nos. 14 and 15), there was an increase in the percentage of fat varying from fifty-five hundredths to a little less than one per cent. This increase in the percentage of fat was followed in the case of cows 1 and 3 by a gradual falling off during the succeeding cow pea test. Cows 2 and 5 gave a decided increase in the percentage of fat during these clover tests, but showed only a slight decrease in the percentages during the succeeding cow pea tests. This circumstance may perhaps be accounted for by the fact that cows 2 and 5 were then well advanced in their periods of lactation. At such a time the percentage of fat becomes naturally high and seems to remain high without very much regard to feed.

During the experiments of 1892 similar tests were made with clover rowen and with Hungarian. From the tables of composition and the rations fed it will be seen that the clover feed in 1892 was not as rich in protein as in 1891. With all but one of the cows there was an increase in the percentage of fat when clover was fed, over that obtained during the Hungarian test just before, and with each cow a marked falling off in milk flow and percentage of fat when the cows were again given Hungarian. It is of interest to note, in connection with the more marked falling off during the second Hungarian test, that the fodder was much poorer in protein, and hence the ration much narrower than the one used just before the clover test.

THE IMPORTANCE OF CLOVERS IN DAIRYING.

As a rule, hay plants contain an excess of woody fiber and starchy materials, and are relatively deficient in nitrogenous matter (protein). A one-sided ration is furnished when hay from grasses is fed. The clovers are rich in protein, and are especially valuable to use with grasses, to balance the ration. When plenty of clover is available, less of such feeds as cotton seed, linseed, and gluten meals which are used mainly to supply protein, need be purchased.

One of the best times to sow clover is about the middle of July, on land from which rye or wheat has been harvested. If sown at this time, at the rate of 12 to 15 pounds to the acre, with one-half bushel of timothy, the crop gets a good start that season and usually winters well.

One drawback to the successful culture of clover, on many farms, seems to be the lack of lime and potash in the soil. Clover thrives best on limestone soils, and responds freely to potash fertilizers.

White clover is the most useful in pasture mixtures. Owing to the low spreading habit of the plant, it will withstand treading and close cropping better than common red clover. From 6 to 8 pounds per acre with blue grass and red top makes a valuable mixture for seeding pasture lands.

The advantages of clover to the dairy farmer may be briefly summed up as follows: It is more valuable than hay or corn stover, in the production of milk; it obtains much of its nitrogen from the air, and can be grown with mineral fertilizers only; it increases the value of the manure; and it tends to improve the soil by the decay of its roots, stubble and leaves, which remain after the crop is harvested.

SUMMARY.

SOILING AND SOILING CROPS.

Under the soiling system more stock can be kept on a given acreage than by pasturing; much of the expense of fencing is saved; nearly all of the food given is available for the formation of products as there is no waste of energy in searching for food; and the manure can be preserved free from waste.

The best crops for soiling are those rich in nitrogenous matter or protein. Although smaller crops are usually obtained with the legumes, (clover, peas, etc.), than with fodder corn, the fodder from the legumes is much richer in nitrogen and hence of more value in the production of milk, cheese, butter and beef. The legumes, being nitrogen collectors, are able to obtain much of their food supply from the air and subsoil. They add to the fertility of the soil by the decay of their roots, stubble, and leaves, which are left in and upon the soil when the crop is harvested.

The more extended use of fodder crops like the clovers, field pea, cow pea, vetch and alfalfa, is a matter that should receive the thoughtful attention of farmers. These crops can all be grown in Connecticut, and with the exception of alfalfa have been successfully grown and fed at the Station during the past four years.

FEEDING EXPERIMENTS WITH MILCH COWS WITH SOILING CROPS.

The best results on quantity and quality of the products were obtained where rations with relatively large amounts of protein were fed. The experiments seem to indicate that rations containing a larger proportion of digestible protein than that called for by the commonly accepted standards are to be preferred. Large nitrogenous rations are especially important early in the period of lactation, when the productive capacity of the cow is most heavily taxed. The quantity and quality of the products may be improved by the use of foods rich in protein, and the manure is more valuable than where starchy foods are fed.

In these experiments when clover was fed the amounts of milk and butter were considerably increased, and the percentages of fat were higher than during the Hungarian test just before and after those with clover. The average product from four cows during the first series of clover tests (Aug. 10, 14 and 18,) of 1891, was, 281 pounds of milk, and 15.6 pounds of butter, and the average percentage of fat was 5.3 per cent.; while for the Hungarian tests (Aug. 3 and 27,) the average quantity of milk was 249 pounds, and of butter 12.9 pounds, and the average percentage of fat 5.0 per cent.

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Results of Experiments with Fertilizers on Different Classes of Soils.

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RESULTS OF EXPERIMENTS WITH FERTILIZERS ON DIFFERENT CLASSES OF SOILS.

BY C. S. PHELPS.

The object of this paper is to summarize the results of about 90 soil test experiments with fertilizers, conducted in this and other New England States during the past 15 years The results of the experiments have been studied with reference to the classes of soils, for the purpose of ascertaining the relations, if any, between the kinds of soils and their deficiencies. The results have been summarized and tabulated in two groups: (1) Soils ranging from sandy to loam, and (2) soils ranging from heavy loams to heavy clays. Many of the experiments could not be included in either of these groups owing to the absence of sufficient data, or the variable character of the soil. In such cases the experiments have been omitted from the tabulations. At the close of this article will be found a series of tables giving the results in detail for the different classes of soils.

EXPERIMENTS MADE DURING THE YEARS 1878–81.

In the year 1877 the Director of this Station, then Director of the Connecticut Agricultural Experiment Station, inaugurated a series of field tests with fertilizers by farmers and scientific men in different parts of the country. The experiments were largely on corn, although potatoes, turnips, oats and other crops were included. They were continued under his direction during a series of years, and in a number of instances are still being carried on. The purpose of the experiments as then stated is given in the following extract from the report of that Station for 1876:

"One of the fundamental results of the vast amount of work done in field experiments with fertilizers is the clear demonstration that soils vary greatly in their capabilities of supplying food to crops, that different ingredients are deficient in different soils, and that the teachings of any given experiment are in the main applicable only to the particular kind of soil on which it is made.

"For farmers who have not their own experience, or that of others in like circumstances, to guide them, the most sensible method for determining what are the deficiencies of their soils, and how they will be the most economically supplied to given crops, is to try experiments on a small scale; to put the question to the soil with different fertilizing materials and obtain its reply in the crops produced."

These experiments were conducted over a wide range of country, although the greater part were in the New England States, New York, and New Jersey. They were carried out in accordance with printed directions sent out by Prof. Atwater. Many were evidently conducted with care and thoroughness, while others were of little value. Those showing discrepancies in the work, or abnormal results due to soil variation, weather, or other causes, have been discarded, and only those used that appeared to furnish results of value. For the purpose of this article, only the experiments made in New England have been included.

Reports on these experiments and tabulations giving results in detail will be found in the reports of the Connecticut Board of Agriculture for the years 1878, 1879, 1880, and 1881, and also in pamphlet form as reported for the U. S. Department of Agriculture in 1883.

The following is taken from the latter report, and indicates some of the difficulties met with and an estimate of the value of the work, by Prof. Atwater, after five years' experience with this class of experiments:

"Many of the reports have no decided story to tell, and some none at all, except failure everywhere. Some were on land so rich that the action of the fertilizers was obscured by the stores of plant-food in the soil; others on soil seemingly in such physical condition that no artificial supply of plant-food could make it fertile. The most serious difficulty of all has been found in the unevenness of the soil. The plots on one side were dryer than on the other; or one plot was on old sod ground and another had been lately cultivated, and showed the effects of previous manuring; while some were irregular for reasons upon which the reports throw no light. On the whole, the general character of the work, as evidenced by the reports, is a most forcible illustration of the truth that among our farmers there is an amount of intelligence and ability which is not appreciated either by themselves or by the community at large, but which is capable of making, indeed is making, a very rapid advance in the intellectual character of our agriculture."

EXPERIMENTS MADE DURING THE YEARS 1888–91.

Since the organization of the Storrs School Station, in 1888, similar soil test experiments with fertilizers have been carried out. The general plan* is the same as for those conducted in this and other States during the years 1878–81. The work, however, has been more closely under the direction of the Station; either the Agriculturist or his assistant having supervision of the more important operations, such as the laying out of plots, application of fertilizers, harvesting and weighing the crop, etc.

The following from a previous report gives the object and purpose of the experiments:

1. To work directly upon farm lands in different parts of the State, and to aid the owners in learning the deficiencies of their soils and the requirements of their crops.

2. To help farmers in becoming familiar with the forms and action of fertilizing materials containing phosphoric acid, potash, and nitrogen, and to better understand their profitable use.

3. To encourage a spirit of investigation, and thus to gradually develop a number of farm experimenters, whose work will be useful not only to themselves, but in a large degree to their communities and to the agriculture of the State.

These experiments are, perhaps, of greater value to the farmer who conducts them than to any one else; not only does he gain a knowledge of particular soils, but at the same time he is led to appreciate the great need and importance of scientific work. Through discussions in Granges and Farmers' Clubs he also succeeds in interesting many others. The value of the tests and their application become more general where they are continued over a period of years.

THE PLAN OF SOIL TEST EXPERIMENTS.

The plan of experiments for soil tests consisted in applying, on parallel plots of land, fertilizers containing nitrogen, phosphoric acid, and potash, singly, two by two, and all three together. The fertilizing materials were in all cases supplied by the Station, in standard commercial forms, and consisted of nitrate of soda, dissolved bone-black, muriate of potash, and land plaster.

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* See Report of this Station, 1890, pp. 87–93.

AVERAGE RESULTS WITH SOIL TESTS ON HEAVY AND LIGHT SOILS.

In table 19, which follows, will be found the average yields of shelled corn for 31 experiments conducted in various parts of New England during the years 1878–81, and 20 experiments made in this State under the charge of the Station in 1888–91. In each case the experiments have been divided into two groups—first, soils ranging from sandy to loam (light soils), and second, from loam to heavy clay (heavy soils).

TABLE 19.

Average Yields of Shelled Corn per Acre on Heavy and Light Soils.

No. of Plot.	KIND OF FERTILIZERS.	1878–1881.				1888–1891.			
		Fertilizers.		Av'g 20 Exp'ts, Light soils.	Av'g 11 Exp'ts, Heavy soils.	Fertilizers.		Av'g 12 Exp'ts, Light soils.	Av'g 8 Exp'ts, Heavy soils.
		Weight.	Cost.			Weight.	Cost.		
		Lbs.	$	Bu.	Bu.	Lbs.	$	Bu.	Bu.
0	Nothing, - -	—	—	25.5	20.8	—	—	16.9	15.3
A	Nitrate of Soda, -	200	7.50	33.3	24.7	160	3.96	22.8	19.5
B	Dis. Bone-black, -	300	5.25	35.1	35.2	320	4.40	19.5	27.2
C	Muriate of Potash,	200	4.50	34.3	25.9	160	3.48	25.9	20.4
D	Nitrate of Soda, - Dis. Bone-black, -	150 300	10.88	41.4	38.8	160 320	8.48	26.8	30.4
E	Nitrate of Soda, - Muriate of Potash,	150 200	10.13	35.5	25.9	160 160	7.52	34.7	19.3
F	Dis. Bone-black, - Muriate of Potash,	300 200	9.75	40.1	38.8	320 160	8.00	28.0	32.9
G	Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash,	150 300 200	15.38	50.3	41.0	160 320 160	12.00	38.4	33.2
H	Plaster, - -	200	.80	27.5	26.4	400	1.70	21.2	18.5
0	Nothing, - -	—	—	31.9	27.6	—	—	18.2	22.3

In table 20, on the next page, are given the average results from the use of the different fertilizing ingredients (nitrogen, phosphoric acid, and potash).

These figures were obtained by averaging the yields on all of the fertilized plots (four) receiving nitrogen, and on all (four) having no nitrogen. The difference between these two averages was considered to be the gain or loss due to the use of nitrogen. The gain or loss from the use of phosphoric acid and potash was obtained in a similar way. By comparing the gain or loss from the use of nitrogen, with the gain or loss from the use of phosphoric acid and potash, it becomes evident which ingredient had the ruling effect in each experiment.

TABLE 20.

Average Yields of Shelled Corn per Acre from the Use of the Different Fertilizing Ingredients.

		Number Experim'ts.	Nitrogen.			Phosphoric Acid.			Potash.		
			Plots With.	Plots Without.	Gain or Loss (−).	Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.
			Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Light Soils	1878-81,	17	38.7	33.8	4.9	39.5	32.9	6.6	38.6	34.0	4.6
	1888-91,	12	30.8	24.5	6.3	27.9	27.8	0.1	31.8	23.0	8.8
	1878-91,	29	35.4	29.9	5.5	34.7	30.7	4.0	35.8	29.5	6.3
Heavy Soils	1878-81,	10	32.5	32.0	0.5	38.2	24.7	13.5	32.6	31.6	1.0
	1888-91,	18	25.6	26.8	−1.2	30.9	19.8	11.1	26.5	26.1	0.4
	1878-91,	18	29.4	29.2	0.2	35.0	22.5	12.5	29.9	29.2	0.7

In the earlier experiments (1878–81) on sandy to loam soils, phosphoric acid had the leading effect in eight experiments, potash in five, nitrogen in three, and nitrogen and potash were alike in one. In the later experiments (1888–91) the lighter soils were more generally benefited by potash fertilizers. Of the twelve experiments on this class of soils all but two showed a marked increase of crop where potash was used; in only one case was there any considerable increase from the use of phosphoric acid, while with nitrogen all but one gave more or less increase.

In the earlier experiments, on heavy loam to heavy clay soils, phosphoric acid had the leading effect in eight experiments, potash in one, and potash and nitrogen were alike in one; while for eight experiments made during 1888-91 on this class of soils, every one showed considerable increase of crop from the use of phosphoric acid, only two gave any increase with potash, while with nitrogen there was no increase of account in any of the experiments.

The results of the earlier experiments on light soils seem to differ somewhat from those made in Connecticut during the past four years. In the earlier experiments, in the majority of cases, phosphoric acid gave the most marked increase of crop, while in several potash produced the greater yield. These experiments indicate that such soils, as a whole, are more apt to be lacking in two or three of the essential ingredients (nitrogen, phosphoric acid, and potash) than are the heavier soils. In the case of experiments made on Connecticut soils of this class since the year 1888 the results are somewhat different. The crops grown on light soils were in nearly all cases greatly increased by the use of potash, or nitrogen, or both, while in only one case was there any considerable increase from the use of phosphoric acid. *The experiments thus far made indicate that for corn on the lighter soils of the State, fertilizers containing a large proportion of potash are needed to give the best results.*

On the other hand, in the case of the heavy soils, nearly all of the experiments recorded indicate a lack of phosphoric acid. With only one or two exceptions, phosphoric acid has greatly increased the yield, especially of grain, while a much smaller increase has resulted from the use of either potash or nitrogen. *The results thus far reached point to the conclusion that for corn, fertilizers with relatively large proportions of phosphoric acid produce the best results on heavy, clayey soils.*

It is of interest also to notice the effect of nitrogen on the two classes of soils. In the majority of cases, on the light soils, corn was considerably benefited by nitrogen. The average increase on the fertilized plots having nitrogen over those without, in 29 experiments on light soils, was 5.5 bushels. In the 18 experiments made on the heavy soils, nitrogen gave an increase above two bushels in only three experiments, and the average yield per acre was only two-tenths of a bushel more with nitrogen than on the plots where no nitrogen was applied. The results seem to indicate that soluble nitrogen compounds, like nitrate of soda, cannot be economically used for corn on heavy soils in this region.

EXPERIMENTS ON POTATOES.

A series of experiments similar to those made on corn during the years 1878–81, were also made on potatoes The kind of fertilizers used and the general plan were the same in the two cases.

The results of fourteen of these experiments have been tabulated and divided into classes according to the character of the soils, the same as for the corn experiments. The number of experiments, however, is too small for making general deductions, although the results appear to be worthy of consideration, as they tend to corroborate those obtained on corn.

TABLE 21.

Average Yields in Potato Experiments (1878–81).

No. of Plot.	FERTILIZERS PER ACRE.			Light Soil Exp't.	Heavy Soil Exp't.
	KIND.	Weight.	Cost.	Bu. per Acre.	Bu. per Acre.
		Lbs.	$		
O.	Nothing,	—	—	65.7	97.9
A.	Nitrate of Soda,	200	7.50	79.0	98.5
B.	Dissolved Bone-black,	300	5.25	91.1	132.1
C.	Muriate of Potash,	200	4.50	96.5	118.7
D.	Nitrate of Soda, Dissolved Bone-black,	150 300	10.88	91.5	147.0
E.	Nitrate of Soda, Muriate of Potash,	150 200	10.13	80.1	105.7
F.	Dissolved Bone-black, Muriate of Potash,	300 200	9.75	103.2	170.6
G.	Nitrate of Soda, Dissolved Bone-black, Muriate of Potash,	150 300 200	15.38	138.9	193.3
H.	Plaster,	200	.80	62.4	117.3
OO.	Nothing,	—	—	—	94.0

TABLE 22.

Average Yields of Potatoes per Acre from the Use of Different Fertilizing Ingredients.

KIND OF SOIL.	Nitrogen.			Phosphoric Acid.			Potash.		
	Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Light Soils,	98.9	92.9	6.0	106.2	85.2	21.0	106.2	85.0	21.1
Heavy Soils,	128.4	121.7	6.7	150.2	98.9	51.3	137.9	112.2	25.7

In table 21 above will be found the average yields per acre on the various plots, and the average yields, together with the gain or loss, from the use of the different fertilizing ingredients.

In the case of the lighter soils only five experiments are reported. In most cases all three ingredients (nitrogen, phosphoric acid, and potash) gave considerable increase in the yield, while the average gain from the use of phosphoric acid was the same as with potash.

With the heaviest soils, in nearly all cases, there was an increase in the yield from each of the essential ingredients, but the increase from the use of phosphoric acid was double that from the use of potash. *These experiments indicate that for potatoes as well as for corn, heavy soils of a clayey character usually need to be supplied with fertilizers containing large amounts of available phosphoric acid, while potash may be more sparingly used.*

EXPERIMENTS BY THE HATCH STATION, MASSACHUSETTS.

A series of soil tests on corn have been carried on for three years in Massachusetts, under the direction of Prof. William Brooks, of Amherst. Nearly all of these were made on light soils, varying from sandy loam to loam. Wherever serious variations appeared, or abnormal yields have occurred, or when the character of the soil could not be determined from the data given, the experiments have not been used for the calculations herewith. Fifteen experiments are here tabulated, all of which were on the lighter soils. The average yields per plot and the average results with nitrogen, phosphoric acid, and potash, are given in the table which follows, for the fifteen experiments on light soils.

TABLE 23.

Experiments on Corn in Massachusetts. Light Soils.

No. of Plot.	FERTILIZERS PER ACRE. Kind.	FERTILIZERS PER ACRE. Weight.	15 Experim'nts Shelled Corn, per Acre.
		Lbs.	Bu.
O.	Nothing, - - - -	—	24.0
A.	Nitrate of Soda, - -	160	31.1
B.	Dissolved Bone-black, -	320	29.2
O.	Nothing, - - - -	—	25.6
C.	Muriate of Potash, -	160	34.8
D.	Nitrate of Soda, - - Dissolved Bone-black, -	160 320	34.0
E.	Nitrate of Soda, - - Muriate of Potash, -	160 160	37.2
O.	Nothing, - - - -	—	27.2
F.	Dissolved Bone-black, - Muriate of Potash, -	320 160	38.8
G.	Nitrate of Soda, - - Dissolved Bone-black, - Muriate of Potash, -	160 320 160	45.2
H.	Plaster, - - - -	160	27.0
O.	Nothing, - - - -	—	26.3

BUSHELS PER ACRE WITH DIFFERENT FERTILIZERS.	Plots With.	Plots Without.	Gain With.
Nitrogen.	36.9	32.5	4.4
Phosphoric Acid.	36.8	32.5	4.3
Potash.	39.0	30.3	8.7

It is of interest to note how generally these soils responded in the crop to the use of potash fertilizers. The results are in close accord with those obtained on soils of the same character in this State, and naturally lead to the conclusion that soils of this character are deficient in available potash and fail to produce good crops unless potash fertilizers are liberally supplied. It seems doubtful, however, if the same results would have followed on heavy, clayey soils, in Massachusetts especially, where such soils are in the granitic regions of the State. Only three of the experiments reported were on clayey soils. Of these two were in the Connecticut valley, in what is known as the old lake bottom of the Hadley meadows. All soils of this region, as far as tested, seem to show a lack of potash, and it is reasonable to conclude that the potash compounds, being more or less soluble, were not deposited from the water of this old lake. The other experiment is in the Housatonic valley, and is described as "alluvial, fine compact loam, with a tendency to clay." This soil is in a limestone region, which fact would probably account for the apparent lack of potash. Soils of this same geological formation, further south in Connecticut, have shown a similar lack of potash.

The soils of the granitic regions of both Connecticut and Massachusetts are quite similar in their origin and composition. As clay is formed from the decomposition of feldspar, from which it gets considerable potash, it is natural to conclude that such soils will not be as noticeably benefited by potash fertilizers as the lighter and more sandy soils. This conclusion is strengthened by experiments made in nearly all the New England States. In almost all experiments reported with corn on clayey soils of granitic origin, potash has caused but little increase of crop, while phosphoric acid has generally given a marked increase.

EXPERIMENTS AT THE RHODE ISLAND STATION.

The experiments reported from Rhode Island were made under the direction of the chemist of the Rhode Island Station, Dr. Wheeler. They are the soil test portions of special nitrogen experiments on corn. The experiments were undertaken for the purpose of studying the deficiencies of soils, and the relative effects of smaller and larger quantities of nitrogen. The special nitrogen portions of the experiments have not been used in this article.

Table 24.

Experiments on Corn in Rhode Island. Light Soils.

Number of Plot.	Fertilizers per Acre.			15 Experiments Shelled Corn, per Acre.
	Kind.	Weight.	Cost.	
		Lbs.	$	Bu.
0	Nothing, - - - -	—	—	20.0
1	Nitrate of Soda, - -	150	3.60	27.3
2	Dissolved Bone-black, -	350	4.38	31.3
3	Muriate of Potash, - -	130	3.06	30.5
4	Nitrate of Soda, - 150 Dis. Bone-black, - 350	500	7.98	39.1
5	Nitrate of Soda, - 150 Muriate of Potash, 130	280	6.66	32.8
6	Dis. Bone-black, - 350 Muriate of Potash, 130	480	7.44	38.3
7	Nitrate of Soda, - 150 Dis. Bone-black, - 350 Muriate of Potash, 130	630	11.04	42.1
00	Nothing, - - -	—	—	24.5

Bushels per Acre with Different Fertilizers.		
Nitrogen.		
Plots With.	Plots Without.	Gain With.
35.7	33.4	2.3
Phosphoric Acid.		
Plots With.	Plots Without.	Gain With.
37.1	30.5	6.6
Potash.		
Plots With.	Plots Without.	Gain With.
35.9	32.6	3.3

Nearly all the experiments were made on the lighter class of soils, varying from sandy to loam. In a few cases the data indicated that the soils were of a clayey character, and these were omitted from the tabulations.

From the results on this class of soils it will be seen that no one ingredient was beneficial to the exclusion of others. Phosphoric acid is seen to have the leading effect on the crop, when the results of the three ingredients are compared. This does not corroborate the results on similar soils in Connecticut and Massachusetts, and goes to show that such soils are not likely to be uniform in their deficiencies.

Many of the experiments were conducted for two successive years on the same soil. In such cases the benefit derived from any single ingredient would be more striking the second season, and hence the average increase from phosphoric acid would probably not have been as great had the experiment been made on a larger number of soils. It would be of interest also to ascertain the results on soils of a clayey nature to compare with those on the lighter soils. From the general similarity of the soils in this State and Rhode Island it would seem probable that the heavier soils would indicate similar needs. In fact, in one or two experiments reported, made on clayey soils, phosphoric acid did produce the most marked effect, although the number of such experiments was not sufficient to warrant their tabulation.

THE VALUE OF THE EXPERIMENTS AND PRACTICAL DEDUCTIONS.

THE VALUE OF SOIL TESTS.

Coöperative field experiments with fertilizers by farmers have become a part of the work of quite a number of the Experiment Stations of the country. They have an especially important place in these States where commercial fertilizers are extensively used. The object aimed at is to study the soils of different regions, learn their deficiencies, and find how to apply fertilizers so as to meet the needs of particular soils and crops in an economical manner.

The wide variations in soils indicate that the results of any one experiment are applicable only to the particular soils experimented upon, or to soils of a similar character. Where this class of experimenting is wholly on the Station farm, the work has only a local value, and in order to make the experiments of highest value to the farmers of the State they must be carried out in a considerable number of places.

If the important operations, such as the selection of the field, the laying out of the plots, the planting, the application of the fertilizers, and the weighing and the harvesting of the crop, are under the supervision of an officer of the Station, there is no reason why the work cannot be carried out with the same degree of accuracy on farms in various parts of State as at the Station.

UNIFORM SOILS AND THOSE DEFICIENT IN PLANT FOOD NEEDED.

For soil test experiments with fertilizers, poor and uniform soils should be selected. The object of such experiments is to learn what the soil can do of itself without the aid of added supplies of plant food, and not to obtain, primarily, large crops.

If the soil lacks uniformity, or has an abundance of available plant-food, it will be impossible to judge how much of the growth is due to the plant-food in the fertilizer applied, and how much to that previously stored in the soil. Just here is the chief difficulty with field experiments, and one that tends to make the results unreliable, unless the experiments are carried through a series of years. It is almost impossible to find a field of one or two acres that is uniform throughout. Soils vary greatly as to the amounts of available plant-food they contain; as to the relative amount of sand, clay, or humus present; as to fineness of texture, slope, powers of absorbing and retaining heat and moisture; and as to their powers of holding, in an available form, the fertilizing ingredients supplied. The subsoil also exerts considerable influence, especially in regulating the supply of moisture from the ground water.

DIFFERENCES IN SOILS.

Connecticut soils, being of the drift formation, are very complex in their make-up. Little can be learned with regard to their composition by a study of the rocks.

One soil may be made up largely of silica or quartz, while only a few rods away another may have been formed from feldspathic or potash containing rocks. Under these circumstances their natural fertility will vary greatly.

Chemical analysis of soils has not been found to be a satisfactory means of determining their fertility. While the analysis may show the composition of the particular sample analyzed, it fails to indicate the amount of plant-food that may be available to the crop.

In the so-called "soil tests" the plant acts as its own chemist. By applying the ingredients most commonly lacking, namely, nitrogen, phosphoric acid, and potash, singly and in combinations, to different plots of land, we enable the plants to draw from the soil the ingredients not supplied. If any of these constituents are already present in the soil in considerable quantities, the results in the crop will soon indicate it, and if any are lacking poor crops will result, until the needed fertilizing materials are supplied in an available form.

THE RELATIVE IMPORTANCE OF PHOSPHORIC ACID AND POTASH.

Many soils have supplies of phosphoric acid and potash that can be drawn upon, year by year, without materially lessening their productiveness. The soils of the Housatonic Valley, which have been experimented upon, seem to contain large quantities of phosphates and to be lacking in potash. In many parts of the State potash feldspar is abundant in the soils, and hence they are generally quite well supplied with potash, although they show a decided lack of phosphoric acid. The beneficial effects of phosphoric acid are especially noticeable in the case of experiments made on the heavy soils in the towns of Lebanon, Putnam, Woodstock, and Pomfret, and this would probably prove true on soils of a similar character in other parts of the State. The work thus far done points strongly to the conclusion that heavy, clayey soils in Connecticut need to be supplied with large amounts of phosphoric acid in the fertilizers used, while light sandy to loam soils are more generally, although not uniformly, helped by potash fertilizers.

IMPORTANCE OF NITROGEN.

Nitrogen holds in plant life and in the economy of the farm a very different position from phosphoric acid, potash, or lime. In the first place, it is the most costly ingredient of fertilizers; and, secondly, it is the most changeable and uncertain. It is supplied to our soils by commercial fertilizers, either as organic compounds, as in dried blood, fish, etc., as salts of ammonia, as sulphate of ammonia, or in the form of nitrates, but it is only in the form of nitrates, as in nitrate of soda, that plants can utilize it to any great extent. The other forms must be partly or entirely changed into nitrates before they become available to the plant. These changes take place after the fertilizer is added to the soil.

Nitrogen is readily lost in the drainage unless there is a crop on the soil that is in condition to utilize it. If the soil is left without a crop for any considerable length of time, much of the nitrogen will pass into the drainage in the form of nitrates. For the same reason, it should not be applied long before the crop is ready to use it. Nitrogen varies in its effects on corn in accordance with the kind of soil. The teaching of the experiments thus far made in Connecticut is that when nitrogen is used on the lighter class of soils the crop is most benefited. Such fertilizers as nitrate of soda and sulphate of ammonia can generally be used with profit on light, loam soils. For some unexplained reason, however, soluble nitrogen compounds, such as nitrate of soda, rarely prove of much value for corn on heavy, clayey soils. Nitrogen is needed in order to get large crops of corn on these soils, and good results are generally obtained from the use of organic nitrogen in the form of slowly decaying vegetable matter.

On such soils the best financial results with corn are generally obtained by the use of yard manures as a source of nitrogen, and by adding commercial fertilizers to supplement the mineral ingredients of the manure that are lacking in the soil.

CONCLUSIONS.

Soils cannot be cultivated to the greatest profit without a knowledge of their deficiencies, as regards plant-food. Soil tests with fertilizers seem to be the best practical means for ascertaining these deficiencies in particular soils.

Heavy, clayey soils need to be supplied with large amounts of phosphoric acid in the fertilizers used, while light, sandy to loam soils are more generally, though not uniformly, helped by potash fertilizers.

The teachings of the experiments thus far made in Connecticut indicate that nitrogen is most beneficial on the light class of soils. Soluble fertilizers, as nitrate of soda and sulphate of ammonia, can generally be used with profit on light, loam soils, but do not prove of much value for corn on heavy soils. For heavy soils nitrogen should be supplied in some organic form, as stable manure, dried blood, etc.

The wide differences found in soils afford a strong argument in favor of home mixed fertilizers. The special needs of different soils cannot be considered by the manufacturer who prepares his fertilizers for general use. The farmer may, however, prepare such mixtures as will meet both the deficiencies of his soil and the requirements of his crops.

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